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HELICOPTER DEVELOPMENT RELIABILITY TEST REQUIREMENTS
VOLUME III
SENSITIVITY ANALYSIS

By

Robert H. Jines

February 1972

EUSTIS DIRECTORATE
U. S. ARMY AIR MOBILITY RESEARCH AND DEVELOPMENT LABORATORY
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THE BOEING COMPANY, VERTOL DIVISION
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Variables used in Volume I, Study Results, which are of the type heavily influenced by management philosophy, available resources, etc., are investigated for their effect on problem identification test costs. Cost optimizations of bench test versus flight test were performed at 126 data points. In particular, the variables studied are: (a) MTBR off-the-board, (b) corrective action efficiency (c) test effectiveness, and (d) test operating time/calendar time. MTBR off-the-board and corrective action efficiency are identified as the variables which can heavily influence the problem identification test costs.

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This report, Volume III of a three-volume report, was prepared by the Boeing-Vertol Division under the terms of Contract DAAJ02-70-C-0039, Amendment P0001. It presents the results of an effort to explore the relationship between test costs and quantitative reliability requirements, as presented in Volume I.

It also examines the sensitivity of the test-cost/reliability relationship to those variables whose specific values were selected through engineering judgments in Volume I.

Volume I gives the results of a study to establish the relationship between various reliability demonstration objectives and the test requirements (type, hours, components required, cost, etc.) necessary to achieve those objectives.

Volume II gives the results of an effort to define and discuss selected terminology, assumptions, and variables used in Volume I. It was prepared to give the nonstatistician a better understanding of the interrelationships of the many parameters associated with reliability demonstration objectives and their test requirements, as addressed in Volumes I and III.

The principal purposes of Volume III are:

a. To allow the Government to evaluate the tolerance of the cost outputs to the input assumptions.

b. To identify areas that can profoundly influence the test-cost/reliability relationship, thus "flagging" them for a high degree of consideration and control by the Government and its contractors.

This report is offered in the continued interest of developing a better understanding of the relationship between helicopter reliability objectives and development test requirements. Although the point estimates of time and dollars contained in the report may not apply to all programs, the trends presented are considered reasonable and should be very useful in helicopter development program planning.

The technical monitor for this contract was Mr. Thomas E. Condon of the Reliability and Maintainability Division of this Directorate.

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HELICOPTER DEVELOPMENT RELIABILITY TEST REQUIREMENTS

VOLUME III

SENSITIVITY ANALYSIS

Final Report

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by
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Prepared by

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SUMMARY

Variables used in Volume I, Study Results, which are of the type heavily influenced by management philosophy, available resources, etc., are investigated for their effect on problem identification test costs. Cost optimizations of bench test versus flight test were performed at 126 data points. The variables studied are:

a. MTBR Off-the-Board

b. Corrective Action Efficiency

c. Test Effectiveness

d. Test Operating Time/Calendar Time

MTBR off-the-board and corrective action efficiency are identified as variables which can heavily influence the problem identification test costs.

FOREWORD

This report covers a study conducted under Contract DAAJ02-70-C-0039, Amendment P0001, (DA Task 1F162203A14301), to establish the sensitivity of the reliability requirement/development test program cost relationship to changes in certain judgementally selected variables. This study identifies some of the factors that require control in order to obtain maximum effectiveness from the reliability test dollar.

USAAMRDL technical direction was provided by Mr. Thomas L. House and Mr. Thomas E. Condon.

The principal Boeing Company, Vertol Division investigator was Mr. Robert H. Jines of the Product Assurance Methodology and Data Control Unit, assisted by Mr. Kirk G. Rummel. Program management and technical direction were provided by Mr. G. W. Windolph, Manager, Product Assurance Technical Staff, and Mr. R. B. Aronson, Unit Chief, Product Assurance Methodology & Data Control Unit.

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LIST OF ABBREVIATIONS

MTBR	mean time between removals
obs	observation(s)
opr	operating (time)
OT/CT	operating time to calendar time relationship
rel	relative
rsts	restraints

DEFINITION OF TERMS

VARIABLES — In this volume, this terminology is used to categorize:

MTBR-Off-the-Board
Test Effectiveness
Corrective Action Efficiency
Operating Time/Calendar Time Ratio

CASE — In this Volume, CASE is used to describe the individual situations that were evaluated for a variable. For example, the following CASES were evaluated under the MTBR-Off-the-Board variable:

High-Frequency Failure Modes Removed
Low-Frequency Failure Modes Removed
25% of Baseline Failure Modes Present
200% of Baseline Failure Modes Present

VALUE — The term VALUE is used to indicate the cost obtained for each individual case.

BASELINE — The term BASELINE refers to the particular case evaluated in Volume I or to the numerical value presented for that case.

1.0 INTRODUCTION

Maintenance requirements for helicopters have always been greater than for comparable fixed-wing aircraft. Helicopter components are relatively complex, particularly in the drive, rotor, and upper controls systems. Since failures in these systems have a potential for causing accidents, maximum reliability becomes paramount. Further, high acquisition and repair costs make maximum reliability a still greater necessity. Both the user and the contractor see the need for improved reliability; but, until now, the development cost impact has been unknown, and reliability growth by product improvement has been slow and costly.

Hardware reliability is produced by two life-cycle activities, as illustrated by Figure 3 of Volume I, "Growth of Component Reliability Through Design and Test". The first, the design process, results in the MTBR off-the-board of the hardware. Design analysis activity is probably the most cost-effective process for obtaining high reliability, since potential problems are identified and corrected before hardware is cut. The technology for achieving the required reliability by this process requires further development, however. The second activity is the process of discovering and eliminating problems in the hardware by operating it, either in special test or in actual service use.

Most programs use the design and operation activities in combination to achieve reliability. This approach will continue, with the emphasis shifting more to problem identification through design analysis, as the technology for this is improved. With current technology, however, extensive problem identification testing must be used to produce the required reliability level.

Determining appropriate levels of Problem Identification Testing to develop components that satisfy reliability requirements necessitates consideration of development test costs, schedules, mixes of techniques, demonstration criteria, and hardware characteristics. Methods for putting these elements into proper perspective were presented in Volume I. Since the true return from the problem identification test funds invested is the resulting actual MTBR of the components, it is highly desirable to understand the sensitivity of Problem Identification Test costs to changes in the input variables. The cost impact of all rigorously quantifiable variables was explored in Volume I. Other variables, heavily influenced by user/contractor management philosophy, and hence less rigorously quantifiable, were evaluated for single values only in Volume I. This sensitivity study, Volume III, evaluates the impact upon

problem identification test costs of several of these management philosophy-influenced variables, and identifies those that have great cost leverage so that they can receive the brunt of management attention. Presented herein are the approach, observations, and conclusions pertinent to the sensitivity analysis of the following variables:

a. MTBR Off-the-Board

b. Corrective Action Efficiency

c. Fraction of Test Restraints Removed

d. Test Operating Time/Calendar Time

The range of values investigated for each variable was based upon a judgement of the current engineering and management technology.

Figure 1 illustrates the interrelationships among the elements affecting reliability test program costs; it also illustrates the points in the flow process where the four variables under investigation exert their respective influence.

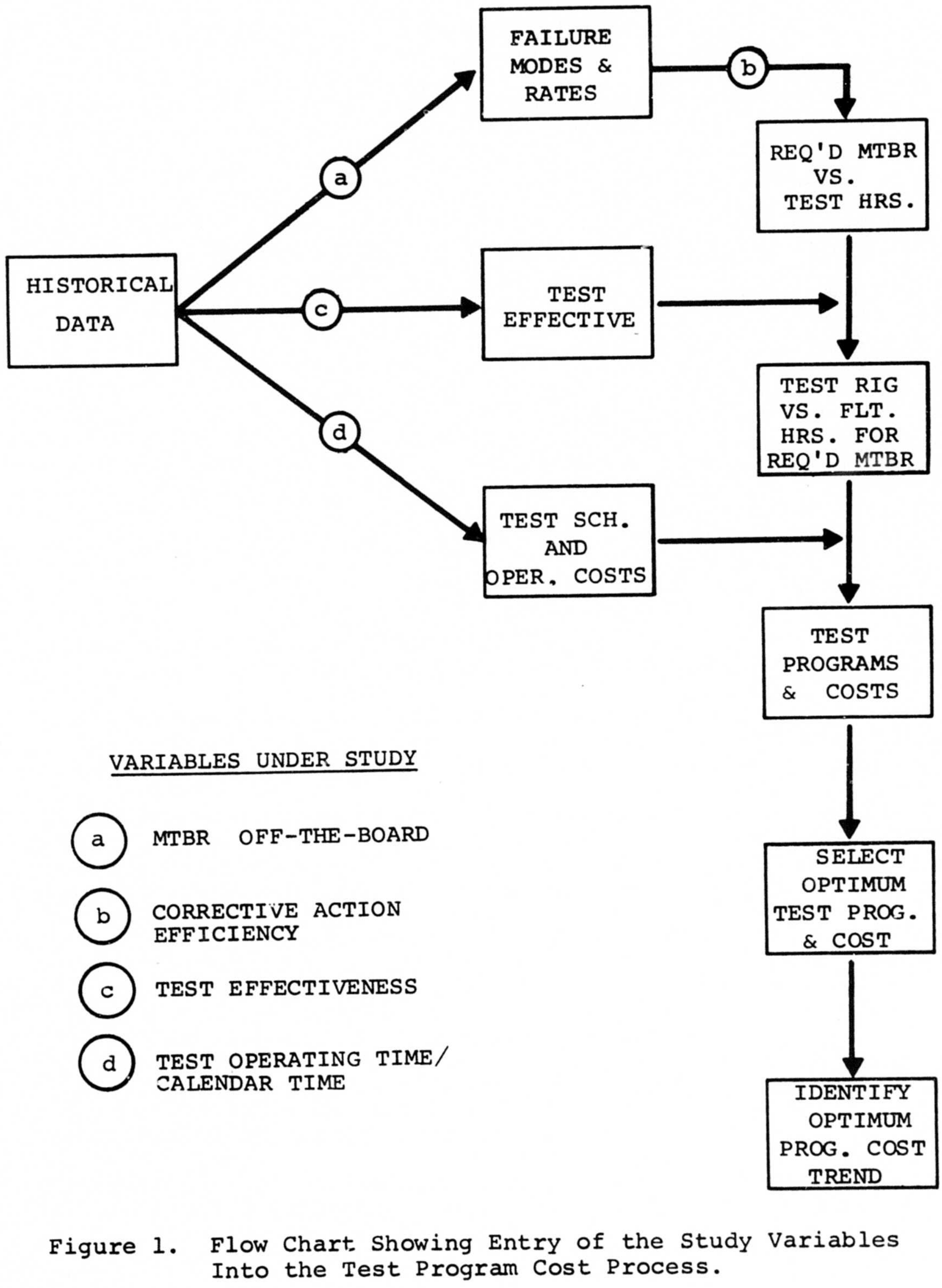

Figure 1. Flow Chart Showing Entry of the Study Variables Into the Test Program Cost Process.

2.0 INDIVIDUAL VARIABLES UNDER INVESTIGATION

Each of the four variables investigated was considered to have great potential for impacting cost.

2.1 MTBR OFF-THE-BOARD

Design and analysis activities are those activities performed during the design phase (prior to building and testing hardware) to improve the reliability of the hardware. They include:

- Development of Criteria
- Goal Apportionment
- Development of Specifications
- Reliability Prediction
- Failure Mode and Effect Analysis
- Design Review

Also included is a series of specialized tests, called design development tests, that occur early in the design phase.

MTBR off-the-board is the reliability level produced by these design and analysis activities prior to application of any reliability problem identification testing.

MTBR off-the-board is predicted using historical data from similar hardware by analyzing the design to identify suspected failure modes and their frequencies. The predictions are appropriate only for an aircraft of specific size and configuration. Engineering judgement, which requires a subjective consideration of the contractor's state-of-the-art ability to make designs problem free, is used in the prediction process. This state of the art varies from component to component, from year to year, and from contractor to contractor. The MTBR off-the-board predictions presented in Volume I reflect the individual component design (size, weight, configuration, loads, etc.) and the specific time at which the design would occur. The predictions reflect the experience of one contractor, with a specific level of effort expended on initial design.

In today's climate of contractual reliability requirements the MTBR predictions presented in Volume I are realistic. The following specific cases are investigated in the sensitivity study reported in Volume III.

Case	Degree of Realism
25% of baseline failure modes present	Optimistic, improbable
Volume I baseline	Expected value
200% of baseline failure modes present	Indicative of poor performance
High-frequency failure modes (1000-hour MTBR or less) not present	Excessive emphasis on frequency*
Low-frequency failure modes (10,000-hour MTBR or greater) not present	Artificial, unrealistic, improbable.

2.2 CORRECTIVE ACTION EFFICIENCY - (Number of Observations Required During Problem Identification Testing To Postulate Corrective Action)

In Volume I, problem identification test costs were established by devising and costing test programs of sufficient duration to produce the required MTBR considered necessary to enter demonstration.

The MTBR off-the-board had been predicted for each failure mode anticipated in the component. Test durations for the test techniques being used were calculated based on these failure modes and their frequencies (reciprocal of MTBR off-the-board) and consideration of the required MTBR for the component. Test conditions (load magnitude, cyclic rate) and test effectiveness for the test technique were considered.

It was postulated that a test duration equal to the MTBR off-the-board of a failure mode would produce one occurrence (observation) of the failure mode. In Volume I it was postulated that in a test duration of twice the MTBR off-the-board of a particular failure mode, the problem would be identified, understood, and adequate design corrective action devised, so that the failure mode would never occur again (termed "Two Observations To Fix"). In this manner, test programs were sized to detect and correct sufficient failure modes so that the net effect of the anticipated remaining modes equaled the required MTBR of the component.

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*This case would result from ranking of problems in order of frequency of occurrence instead of assessing problem consequence and the cost effectiveness of corrective action.

The two-observations-to-fix philosophy postulated in Volume I is optimistic, even where a contractual numerical reliability demonstration requirement is imposed. Three or even four observations to postulate development of corrective action is more realistic. For the study reported herein, the following specific cases were studied:

Case	Degree of Realism
2 Observations to fix (Volume I baseline)	Optimistic
4 Observations to fix	Realistic
8 Observations to fix	Indicative of unwillingness to acknowledge problems or inefficiency in correcting them

2.3 TEST EFFECTIVENESS

Effectiveness is defined as the ability of a test technique to detect a potential field problem. Correction of problems after they are detected does not differ significantly among test techniques. Therefore, the main concern is the detection ability of each test technique.

In support of the evaluation reported in Volume I, CH-47 test and service experience was reviewed. A large percentage (74 percent) of CH-47 problems were detected by the total test program, but no individual test technique detected all the problems. Furthermore, the full detection potential of each test technique was not manifested in the test results. Many problems were not detected during certain tests for reasons which were completely unrelated to the actual test techniques used. These reasons were termed artificial restraints. The term inherent restraints was used for those test technique limitations which stem from the specific load, speeds, configurations, or climatic environments (dust, humidity, temperature, etc.) of each test technique.

The artificial restraints observed in the CH-47 test program were classified as follows:

Configuration

Many problems which first appeared in early tests were completely corrected. Later test specimens incorporated these design changes and therefore did not fail during subsequent tests using other techniques.

In other instances, a failure mode caused by a manufacturing or material error happened to appear in a specimen that was being tested by a given test technique. Other test techniques could have detected the failure mode if the necessary conditions were present in the specimen.

Maintenance

Maintenance damage caused many failure modes. Often, these failure modes were not detected during test because of the unreal maintenance environment. The manner in which the hardware was installed in the test fixture also precluded the appearance of certain maintenance-induced problems.

Test Acceptance Criteria

A significant number of problems actually occurred during tests but were not recorded, reported, or corrected because the criteria under which the test was operating did not require such recognition. Failure modes which involved a measure of degree (e.g., wear, fretting, leakage) were particularly susceptible to being overlooked. Emphasis was placed upon those modes which caused the component to fail to operate.

Test Procedures

In certain instances, the design contained features which were not used during testing. In-service use of these features resulted in subsequent failures. For example, a quick-disconnect feature was incorporated into the CH-47 lag damper/rotor head assembly. Use of this feature in the field soon resulted in the discovery of an understrength sheet metal bracket, the repair of which required rotor head removal. Exercising this quick-disconnect feature during whirl tower testing would have brought out the full problem detection potential of the whirl tower test.

The above artificial restraints prevented many problems from being detected by specific test techniques. They did not, however, detract from the problem-detection potential of a given test technique. Also, a test technique might not have been used long enough to detect the problem. If a failure mode had MTBR in excess of the test duration, it would have a low probability of appearance despite the fact that there was no inherent restraint.

For these reasons, a comparison of test and field identified problems must acknowledge four categories:

- Problems that were actually detected during test technique application

- Problems that could have been detected except for the presence of artificial restraints

- Problems that could have been detected if the test technique had been used long enough

- Problems that could not be detected because of inherent restraints

The full detection potential of any test technique is represented by the sum of the first three categories.

For the Volume I study, it was assumed that all artificial restraints were removed. This is considered to be a reasonable assumption given a contractual reliability demonstration requirement. The following specific cases were investigated in this study:

Case	Degree of Realism
All (artificial and inherent) restraints removed	Reflects ideal case where test fixture has flight test effectiveness
Volume I baseline (all artificial restraints removed)	Realistic
Maintenance and test acceptance criteria artificial restraints not removed (test procedure and configuration artificial restraints removed)	Reflects unrealistic attitude for the contractual environment

Table I contains the test effectiveness percentages used for the Sensitivity Study.

2.4 TEST TECHNIQUE OPERATING TIME/CALENDAR TIME RELATIONSHIP

Schedules for each test technique are defined by two distinct characteristics. The first is the lead time necessary from the go-ahead decision to the point where the test fixture is available for operation. The second is the quantity of test hours that can be accumulated in a given calendar period. This has been termed the operational rate. Both factors are extremely important in determining the costs of test programs, since they determine the number of test rigs required to fulfill a given test duration in a given calendar period.

TABLE I. TEST EFFECTIVENESS				
Component	Test Fixture	With Inherent and Artificial Restraints	Artificial Restraints Removed	No Restraints
Main Xmsn	Closed Loop	80%	92%	100%
Main Hub	Whirl Tower	85	85	100
Main Controls	Whirl Tower	75	85	100
Main Controls	Bench	75	85	100
Main Blades	Whirl Tower	65	65	100
Intermediate Gearbox	Tail Rotor Stand	67	90	100
Tail Rotor Gearbox	Tail Rotor Stand	65	85	100
Tail Rotor Hub	Tail Rotor Stand	85	85	100
Tail Rotor Blade	Tail Rotor Stand	65	65	100
Tail Rotor Shaft	Tail Rotor Stand	90	90	100

The schedule characteristics presented in Volume I were derived through review of data on the CH-47. Subsequently, adjustments were made to reflect certain assumptions:

1. All tests operated for 3 shifts each day, 7 days a week.

2. No interruptions in developmental tests permitted for production usage of the test facility.

3. Additional specimens available to immediately replace test specimens which have failed or require removal.

4. Test stand reliability representative of mature equipment.

5. Lead times to procure fixtures assume a degree of pre-implementation traditional in aircraft programs, i.e., basic conceptual and sizing efforts completed, but detail design must await contract go-ahead.

The following helicopter 'A' test technique operational rates were used in Volume I:

Test Technique	Operational Rate (hours/month)
Controls bench, back-to-back	500
Controls bench, single specimen	500
Tiedown	165
Dynamic systems test	200
Whirl tower	350
Transmission closed loop	400
Tail rotor whirl tower	400
Alaska climatic	20
Yuma climatic	20
Flight	70

The above rates present an upper limit of contractor efficiency. This sensitivity study, accordingly, investigates the following cases:

Case	Degree of Realism
Volume I Baseline	Optimistic, represents an achievable upper limit
0.5 x Baseline	Realistic, achievable with reasonable effort

Case	Degree of Realism
0.25 x Baseline	Not representative of a reasonable effort, in a contractual reliability demonstration environment

Table II shows the limiting run time per rig used in the study.

TABLE II. TEST RIG RUN TIMES

Test Rig	Program Length, (Years)	Limiting Run Time Per Rig (hours)		
		Study	0.5 x Study	0.25 x Study
Xmsn	3	7,200	3,600	1,800
Closed	4	12,000	6,000	3,000
Loop	6	21,600	10,800	5,400
Whirl	3	5,600	2,800	1,400
Tower	4	9,800	4,900	2,450
	6	18,200	9,100	4,550
Tail	3	8,000	4,000	2,000
Rotor	4	12,800	6,400	3,200
Stand	6	22,400	11,200	5,600
Control	3	15,000	7,500	3,750
Bench	4	21,000	10,500	5,250
	6	33,000	16,500	8,250

3.0 STUDY PROCEDURES AND GROUND RULES

3.1 PROCEDURES

The calculation techniques for the basic study, Volume I, with the following modifications, define the approach to the sensitivity study:

- Cost, schedule, failure modes and failure rate distributions, and other data are the same as used for Volume I. This includes data presented in Tables XV & XVI, and Appendices II & IV of Volume I. No new data was generated for the sensitivity study.

- All values used were held constant, with the exception of the value of the variable being studied. In the "combined worst case" analysis,all investigated variables were altered simultaneously.

- A study was performed for a bench plus flight type program, and a flight test versus bench test cost optimization analysis was performed for each case of each variable under study. (This procedure resulted in 126 cost data points being calculated. A sample cost optimization plot is shown in Figure 2, which illustrates the procedure followed.)

- Each cost data point was divided by the associated baseline cost from Volume I to normalize the data for comparison purposes. Baseline costs are tabulated in Table V, page 38.

- The resulting cost normalizations were then used to evaluate problem identification test cost trends vs. program elapsed time. The calculation involved averaging appropriate 600-, 3000-, & 5200-hour MTBR costs for a 3- or 6-year program and dividing the result by a similarly averaged value for a 4-year program. Table VI is a tabulation of the resulting ratios for each study case.

3.2 GROUND RULES

The following ground rules were applied to the study:

- 3-, 4-, and 6-year development program elapsed time data points were calculated.

- Only the 600-, 3000- and 5200-hour required MTBR data points were calculated.

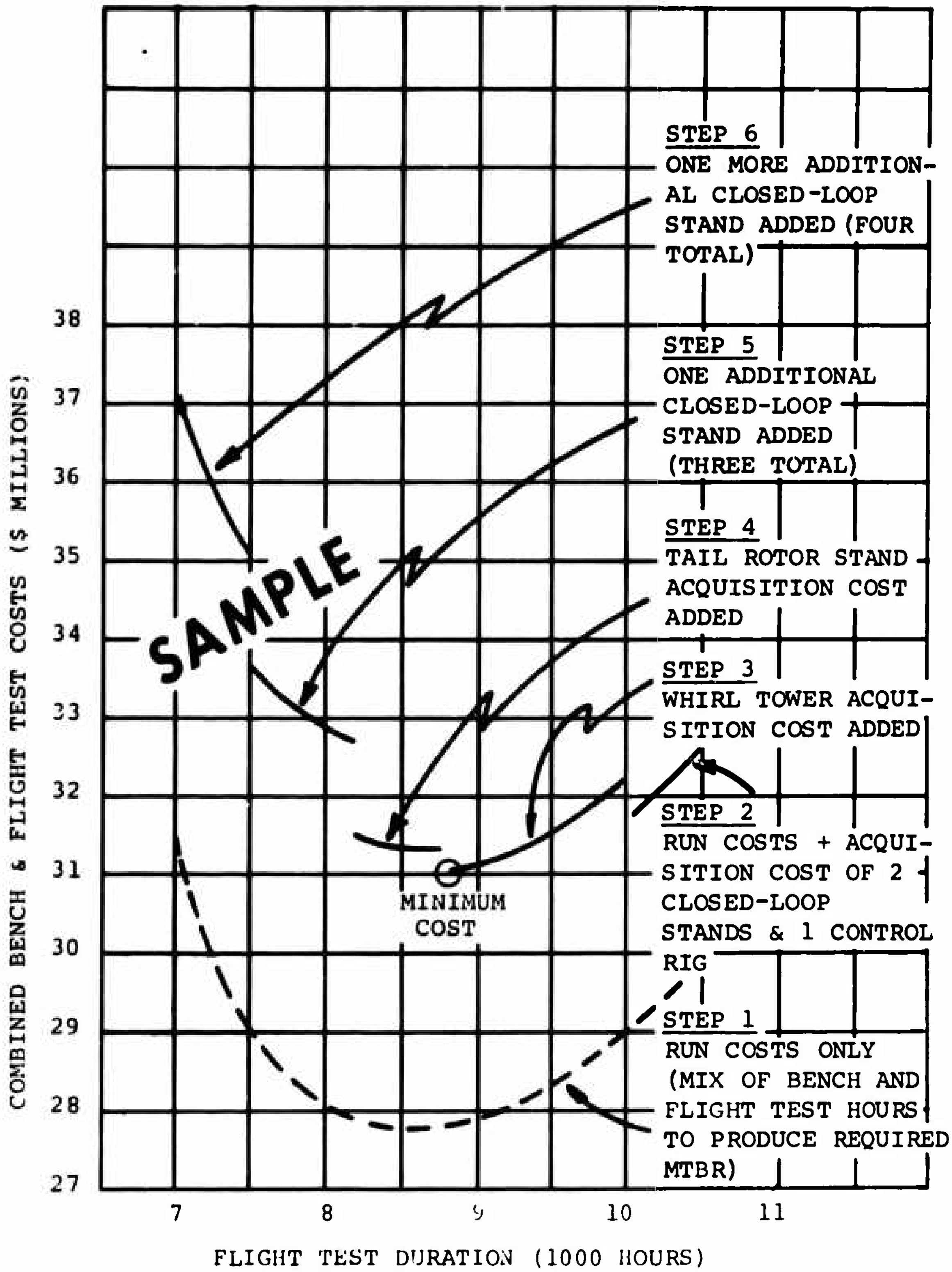

Figure 2. Example of the Optimization Process (Decreasing Flight Test Duration Causes Increased Bench Test Cost).

- Problem identification test durations for each test rig are derived for the component which paced that rig in the basic study (Volume I) for all study variables except "Test Effectiveness". (Verification checks indicated that the pacing components would not change.) In the case of Test Effectiveness, all components were reviewed to identify the pacing component, since individual artificial restraints operated on individual component failure modes.

- Only problem identification test costs (Type II) were included in the sensitivity analysis. (Demonstration costs and Type I costs were not considered.)

- Only Helicopter 'A' analyses were performed.

- Component bench tests were supplemented by Type I and II flight test. 1500 hours of "free" Type I flight test were applied to each program.

- The number of aircraft available for both Type I and Type II testing was considered to be limited only by the aircraft delivery schedule. The delivery rate was assumed to be three aircraft per month for this study. Table III shows the maximum total flight test hours possible for 3-, 4-, and 6-year problem identification programs. Lead time for delivery of the first aircraft was 2 years in every case. The minimum number of flight hours considered adequate on any individual aircraft was 140. Because the number of aircraft produced is independent on the length of production, 1- and 2-year delivery programs are shown.

TABLE III. LIMITING VALUES FOR FLIGHT TESTING

Program Length (Years)	Number of Aircraft		Total Flight Hours Possible, Type I and Type II Flight	
	1-Year Delivery	2-Year Delivery	1-Year Delivery	2-Year Delivery
3	30	N/A	12,000	N/A
4	30	66	37,200	58,620
6	30	66	87,600	114,060

If program duration permits a 2-year delivery schedule for the flight test aircraft, sufficient flight hours for the test programs can always be developed. For the 3-year program duration, the 2-year lead time requirement prevents a 2-year delivery schedule. In these cases, the aircraft delivery period was restricted to 1 year. In many of these cases, this provided sufficient flight test hours for program optimization. However, in a few cases, as in Figures 6, 10, 13, 14, and 15, this was not so, and less efficient test techniques had to be used in order to reach the required MTBR levels.

In a typical test program, it is desirable to get high test times on each aircraft. This approach causes the program to strive for production of a minimum number of aircraft with delivery as early as possible. However, the question "What happens to the production line in the period between the end of delivery of problem identification aircraft and the start of production delivery?" must eventually be considered.

4.0 DETAILED RESULTS AND DISCUSSION

4.1 MTBR OFF-THE-BOARD

Results

The test programs resulting from the flight test versus bench test cost optimization procedure application for the various MTBR off-the-board variations are shown in Appendix I. The number of test rigs, test rig acquisition costs, test rig run costs, number of flight test hours in program, flight test costs, total run costs (test rig plus flight test), and total program costs (acquisition plus run costs) are listed.

The 3-, 4-, and 6-year development program "Problem Identification Test Costs" vs. "Required MTBR Achieved" plots are contained in Figures 16, 17, and 18, in Appendix II.

Figures 3, 4, and 5 plot the ratio of test cost/baseline test costs versus required MTBR achieved for the variations in MTBR off-the-board, for 3-, 4-, and 6-year programs. In each figure, Case "A" represents the baseline case evaluated in Volume I.

Table V, page 38, lists the absolute values of problem identification test program costs and test cost/baseline test cost ratios for each of the cases evaluated, as well as the baseline case absolute values from Volume I.

Discussion

MTBR off-the-board, in general, was found to be a powerful driving force upon the numerical reliability requirement/test program cost relationship. The following discussions pertain to the individual cases investigated.

Elimination of High-Frequency Failure Modes

Of all the MTBR off-the-board cases investigated, elimination of those failure modes with a high frequency of occurrence had the least impact on cost. The problem identification test durations required to produce the typical level of "required MTBR achieved" are such that all of the high-frequency failure modes and many relatively low-frequency failure modes must be identified and corrected. Detection of the low-frequency modes requires problem identification test durations in excess of those required to detect the high-frequency modes. Application of 1500 hours of "free" (Type I) flight test to the problem identification test program further desensitizes the effect of high-frequency mode elimination.

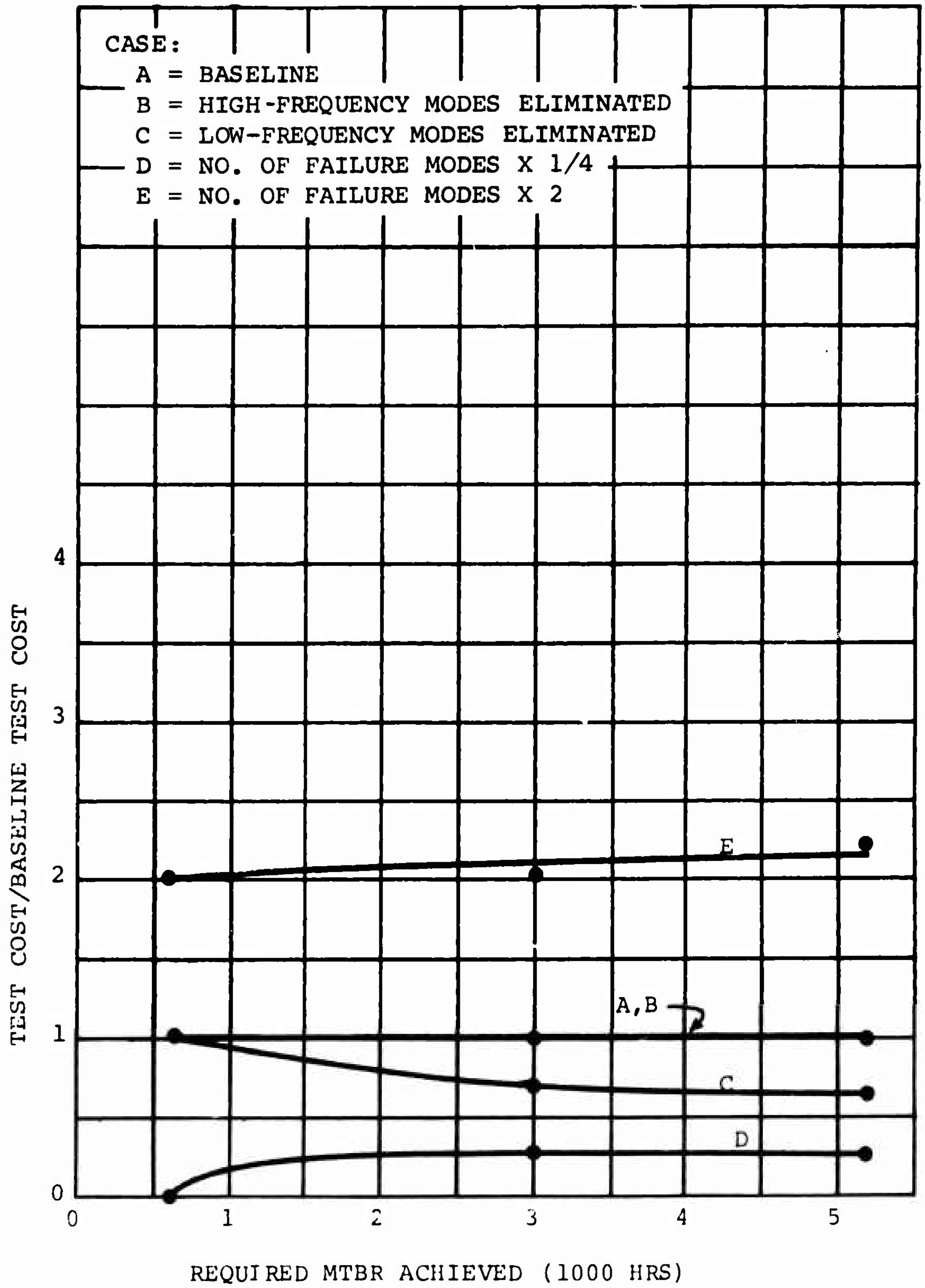

Figure 3. 3-Year Program MTBR Off-the-Board Sensitivity - Ratio of Study Value and Baseline Value Problem Identification Test Costs.

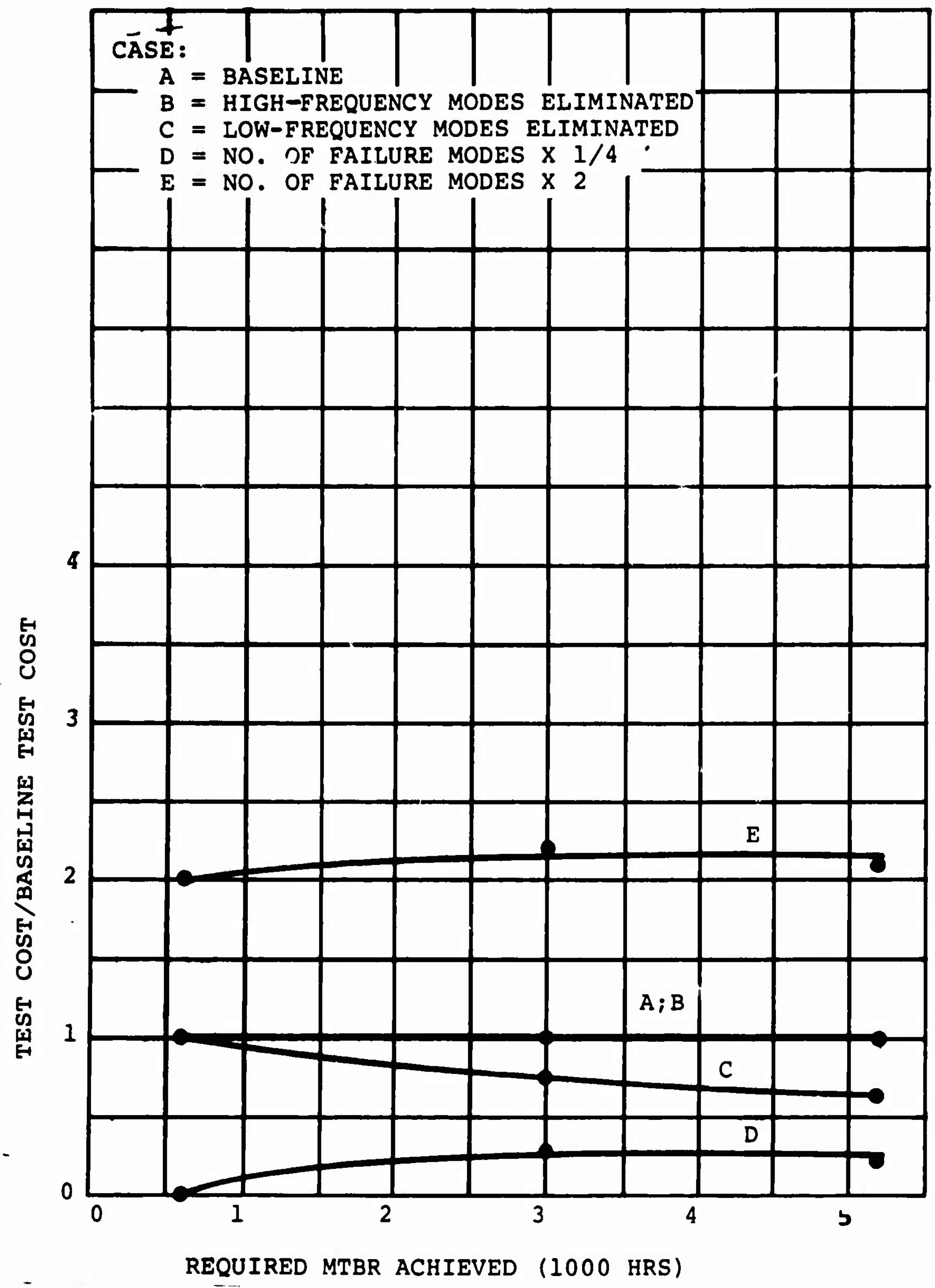

Figure 4. 4-Year Program MTBR Off-the-Board Sensitivity - Ratio of Study Value and Baseline Value Problem Identification Test Costs.

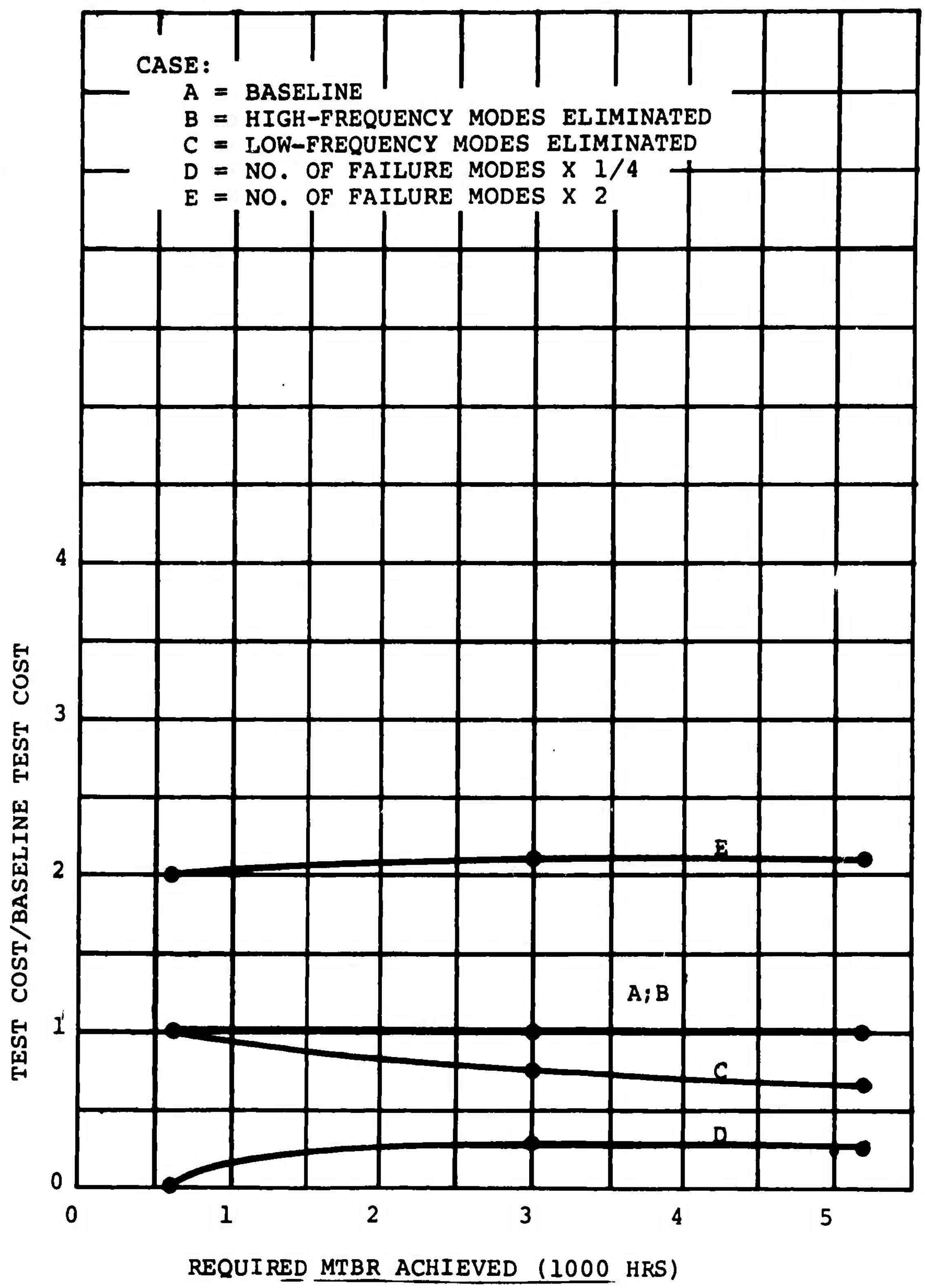

Figure 5. 6-Year Program MTBR Off-the-Board Sensitivity - Ratio of Study Value and Baseline Value Problem Identification Test Costs.

For Example:

> For the "two observations to postulate corrective action" philosophy, all failure modes of 1000 hours or less are assumed to be identified and corrected with 2000 hours of problem identification testing. Seventy-five percent of these failure modes are accounted for by the "free" Type I flight testing.

Results of sensitivity analysis indicated no change in test costs for any of the values calculated, through elimination of all modes with a 1000-hour MTBR or less.

There is a significant lesson to be learned here. Traditionally, attention in the reliability area has been focused upon the "Top Ten (or more) Problems" ranked by frequency of occurrence. The sensitivity study shows that this emphasis has no impact on test costs and, as shown in Volume I, is inadequate to produce the levels of reliability necessary for the next generation.

Elimination of Low-Frequency Failure Modes

For higher values of required MTBR achieved (3000 and 5200 hours), elimination of the low-frequency failure modes has a profound effect on test costs.

No change in test costs was observed, however, for the 600-hour required MTBR achieved value.

From a practical standpoint, it will be difficult to profit from this approach in an applied program. Emphasis has always been placed upon elimination of problems that occur frequently. Infrequently occurring failures traditionally are dismissed as isolated cases and are usually ignored. Yet it is this pool of isolated failure modes that prevents high MTBR's from being achieved. In the next generation of hardware development, considerable emphasis must be placed upon elimination of failure modes over a wide range of frequencies in the off-the-board design.

Changes Affecting the Entire Failure Mode Distribution

Increases or decreases in the number of failure modes across the spectrum of frequencies have a significant influence upon test costs, and represent conditions that can be encountered in applied programs.

Poor design practices and little attention paid to reliability in the trade-off process will probably result in an across-the-board increase in the number of failure modes present in the design.

Similarly, an across-the-board decrease in the number of failure modes present is likely, if careful attention is paid to design and those factors which improve reliability.

The sensitivity study indicates a nearly direct relationship between the percentage of change in problem identification test costs and the percentage of change in the number of failure modes present, except in the area of large reductions in the number of modes in the relatively low required MTBR achieved range. This latter effect results from the assumption that 1500 hours of "free" (Type I) flight test is available, which tends to decrease cost sensitivity for relatively short programs.

4.2 CORRECTIVE ACTION EFFICIENCY

Results

The test programs resulting from the flight test versus bench test cost optimization for each corrective action efficiency study case are shown in Appendix I.

The 3-, 4-, and 6-year problem identification test costs versus required MTBR achieved plots are contained in Figures 19, 20, and 21 in Appendix II.

Figures 6, 7, and 8 contain plots of costs relative to the associated baseline versus required MTBR achieved for 3, 4-, and 6-year programs, respectively. In each figure, Case "A" represents the baseline case evaluated in Volume I.

Absolute values of problem identification program test cost and the cost relative to the associated baseline cost for each corrective action efficiency value are summarized in Table V, on page 38. Table V also lists the baseline case absolute values from Volume I.

Discussion

Corrective action efficiency is a prime factor driving the problem identification test costs. In general, the percentage of test cost increase is equal to the percentage of increase in the test duration postulated to result in correction of a failure mode. For example, in most circumstances, where testing durations equal to four times the MTBR are required for problem correction, the test costs are roughly twice the cost of a program where testing durations equal to twice the MTBR are required. For low values of required MTBR, the relationship does not hold, due to the variations in the effect of the "free" Type I flight testing. (Type I testing, here, represents a large portion of the total testing.)

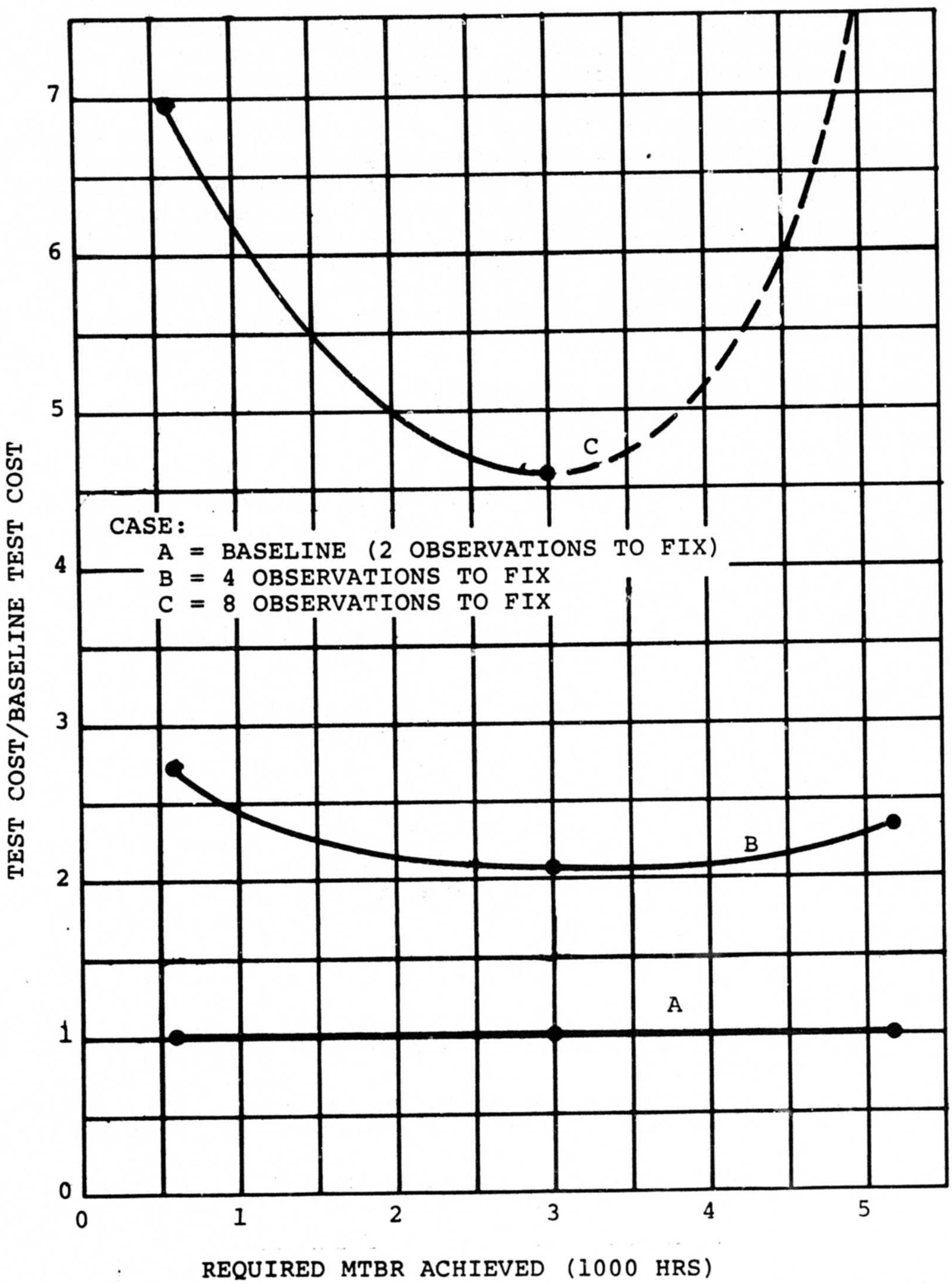

Figure 6. 3-Year Program Corrective Action Efficiency Sensitivity - Ratio of Study Value and Baseline Value Problem Identification Test Costs.

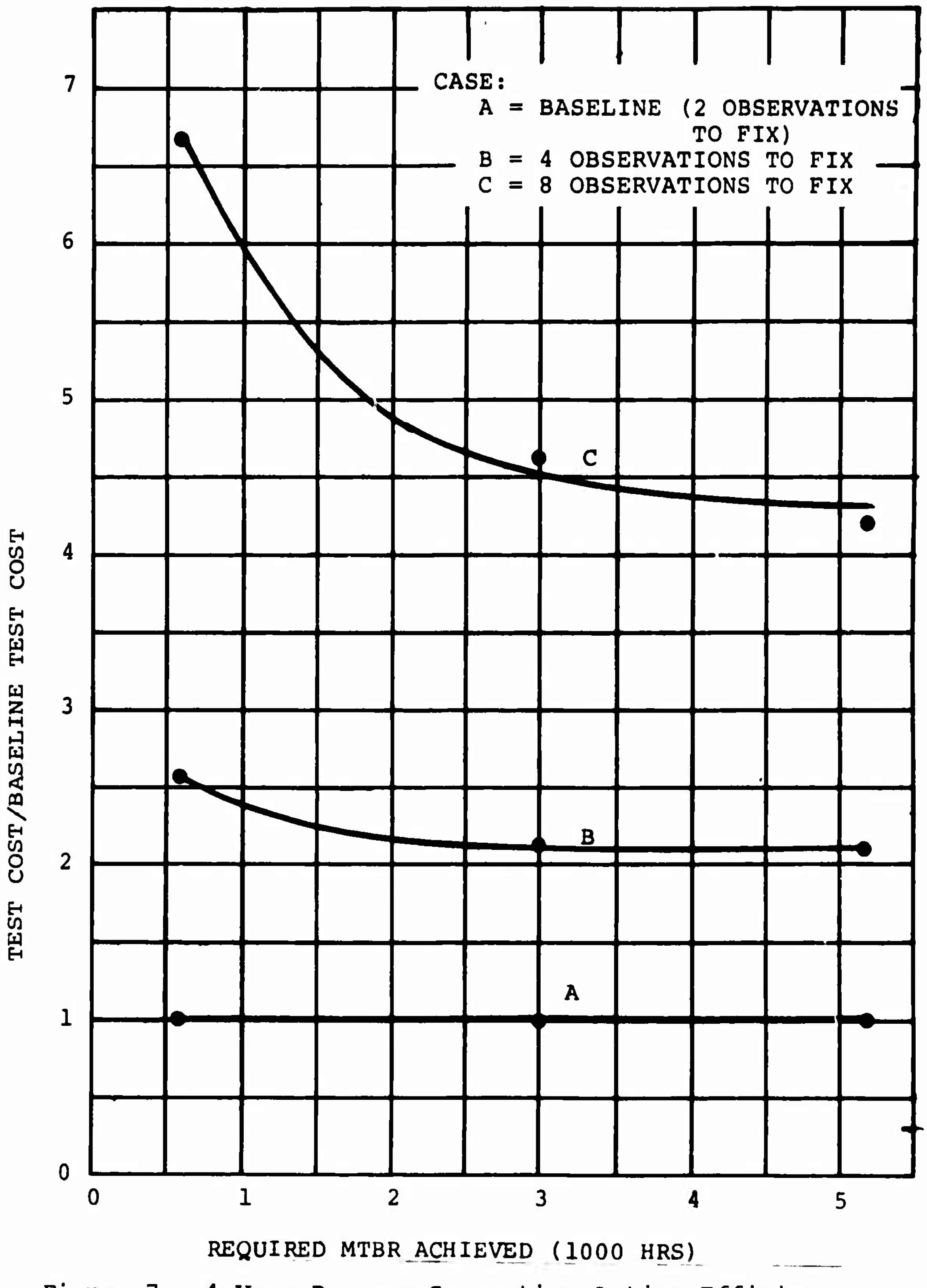

Figure 7. 4-Year Program Corrective Action Efficiency Sensitivity - Ratio of Study Value and Baseline Value Problem Identification Test Costs.

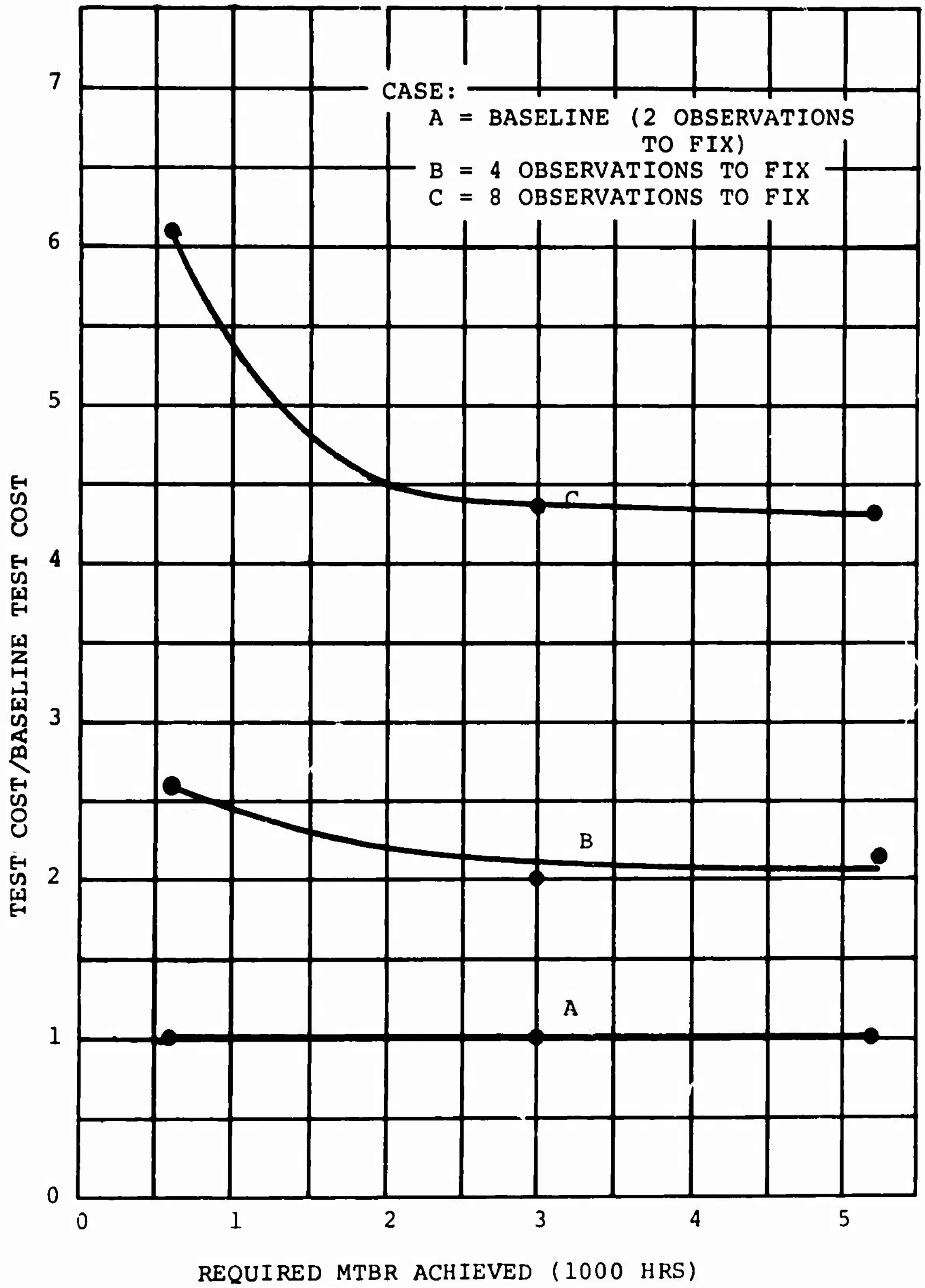

Figure 8. 6-Year Program Corrective Action Efficiency Sensitivity - Ratio of Study Value and Baseline Value Problem Identification Test Costs.

The effect of the above discussion is seen in Figures 6, 7, and 8 as a rise in the curves as required MTBR is decreased.

From a practical standpoint, corrective action efficiency is significant in an applied program. Willingness to acknowledge and correct problems is greatly influenced by contract requirements. Hence, these requirements have a direct influence on the cost of the problem identification test program in terms of receptiveness to problem acknowledgement.

4.3 TEST EFFECTIVENESS

Results

The optimized test programs for the test effectiveness sensitivity study are shown in Appendix I.

The 3-, 4-, and 6-year problem identification test programs cost versus required MTBR achieved plots are contained in Figures 22, 23, and 24 of Appendix II.

Figure 9 contains the plot of cost relative to the associated baseline versus required MTBR achieved for the 3-, 4-, and 6-year programs. Case "A" represents the baseline case evaluated in Volume I.

Problem identification test costs and the cost relative to the associated baseline costs for each test effectiveness study are summarized in Table V, on page 38. Table V lists the baseline case absolute values from Volume I.

Discussion

The process of optimizing flight test vs. bench test reduces the sensitivity of problem identification test costs to test effectiveness. The relative insensitivity of costs to this variable are best established by considering the limiting cases.

Maximum costs would occur if the bench test effectiveness were zero. Then, the test program would become all flight test, with an associated cost of from 1.5 to 2.0 times the baseline problem identification test costs. Minimum costs would occur if there were no inherent or artificial restraints imposed upon bench test (100% test effectiveness). In this case, the test program would be all bench test except for the "free" type I flight test. Here, minimum costs range from 0.5 to 1.0 times the baseline problem identification test costs.

For the realistic case where maintenance and test acceptance criteria artificial restraints are not eliminated, the problem identification test costs are approximately 1.3 times the baseline value.

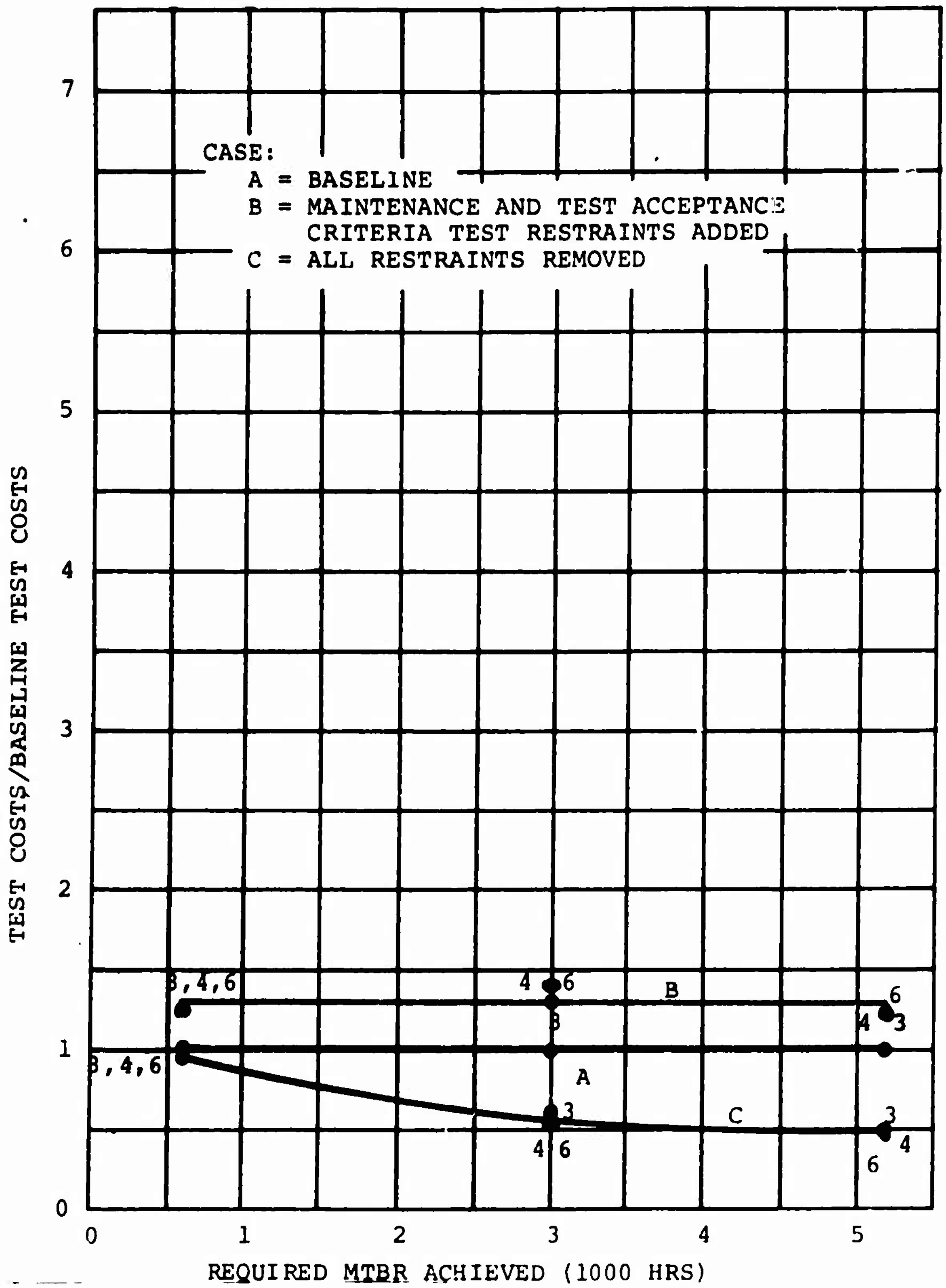

Figure 9. 3-, 4- and 6-Year Programs Test Effectiveness Sensitivity - Ratio of Study Value and Baseline Value Problem Identification Test Costs for Required MTBR's.

4.4 TEST OPERATING TIME/CALENDAR TIME RELATIONSHIP

Results

The test-programs resulting from the flight test versus bench test cost optimization for each test operating time/calendar time study parameter are shown in Appendix I.

The 3-, 4-, and 6-year Problem Identification Test Costs versus required MTBR achieved plots are contained in Figures 25, 26, and 27, in Appendix II.

Figures 10, 11, and 12 contain the plots of costs relative to the associated baseline versus required MTBR achieved for 3-, 4-, and 6-year programs, respectively. In each figure, Case "A" represents the baseline case evaluated in Volume I.

Absolute values of problem identification test costs and the cost relative to the associated baseline cost for each test operating time/calendar time case are summarized in Table V, on page 38. Table V also lists the baseline case absolute values from Volume I.

Discussion

In general, the problem identification test costs are insensitive to changes in the operating time/calendar time relationship.

Only the 3-year program is affected when the flight test hours are assumed to be reduced along with bench test hours. For high required MTBR achieved values, the aircraft production limit is reached and the number of available flight hours becomes fixed. This is shown in Figure 10 by curves D and E.

Fixing the available flight hours forces the use of excessive amounts of bench test, reflecting the inefficiency of certain test techniques. In the case of the 25% of baseline run time, required MTBR's much above 4,000 hours cannot be reached by increasing bench test duration. This is illustrated in curve E of Figure 10 by the dashed portion of the curve. Curve D (50% x OT/CT, flight test included) of Figure 10 shows a rapid increase in the relative cost as the value of required MTBR achieved is increased. In this instance the flight hour limit is reached but the MTBR is still achieved by increased levels of bench testing. Extension of the required MTBR much past 5200 hours would result in a sharp cost ratio increase similar to that of curve E (Figure 10).

Except as discussed above, the flight limits are not reached during the cost optimization process, regardless of whether the flight hours are reduced along with the bench test hours.

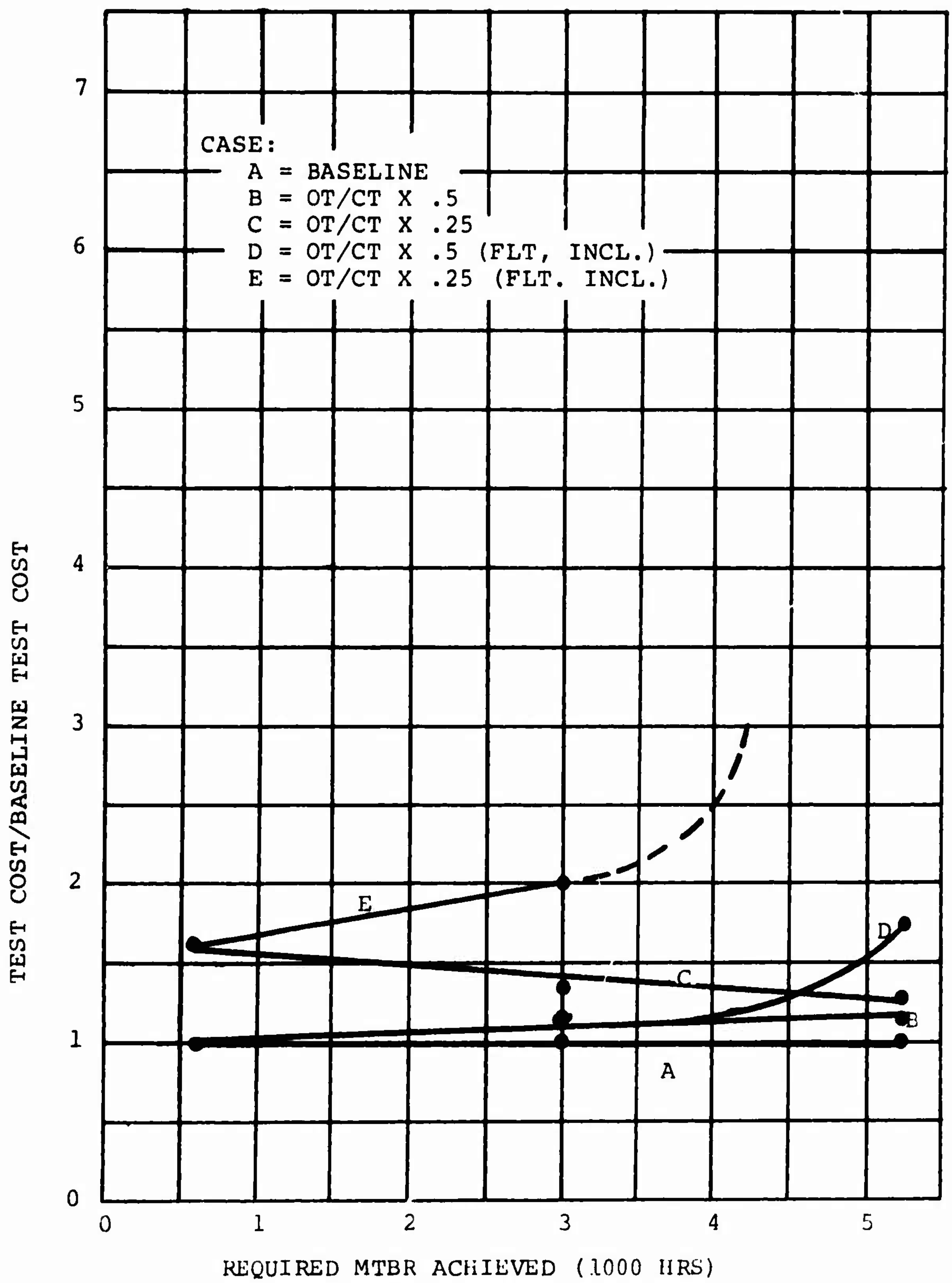

Figure 10. 3-Year Program Operating Time to Calendar Time Sensitivity - Ratio of Study Value and Baseline Value Problem Identification Test Costs.

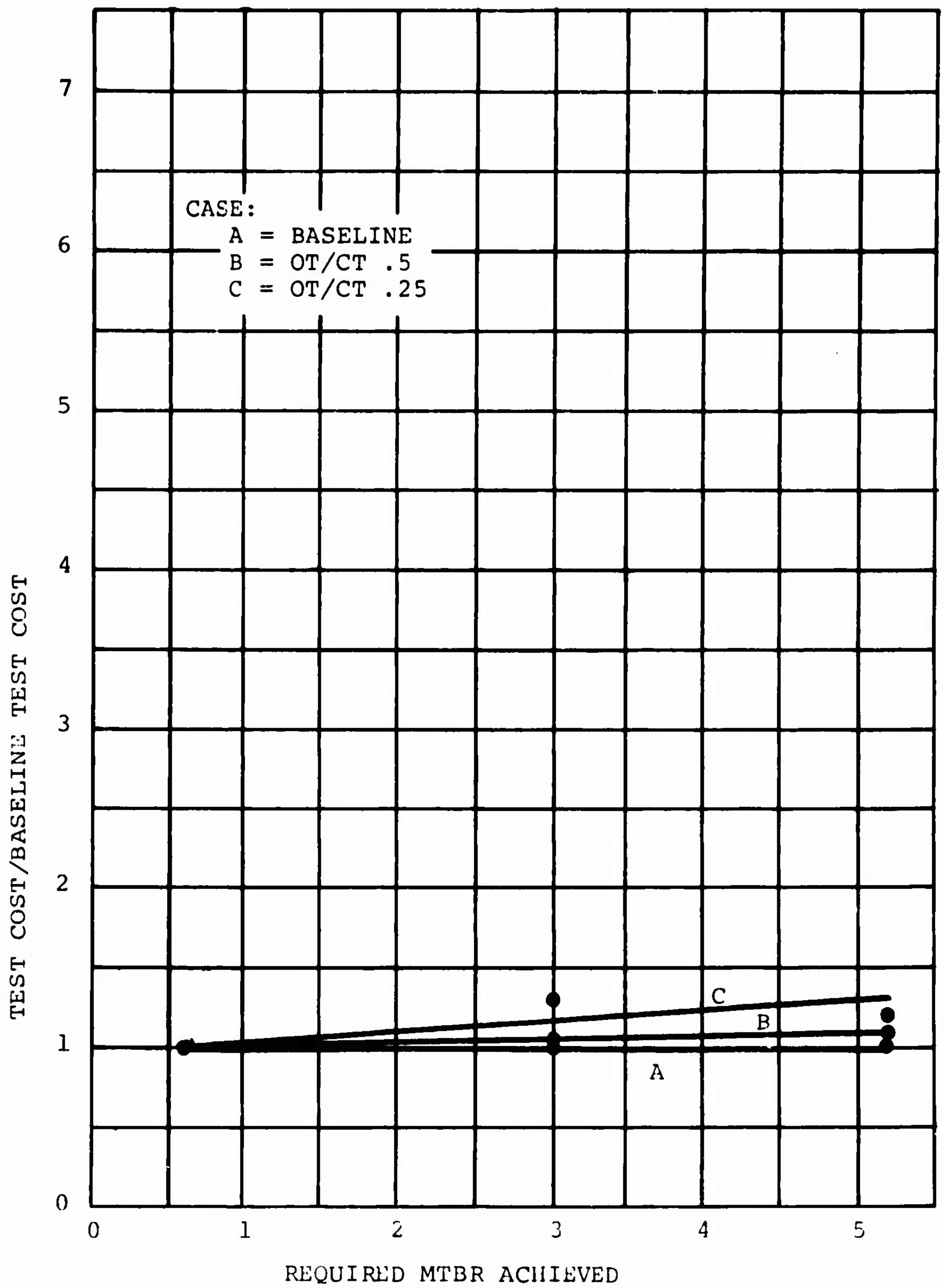

Figure 11. 4-Year Program Operating Time to Calendar Time Sensitivity - Ratio of Study Value and Baseline Value Problem Identification Test Costs for Required MTBR's.

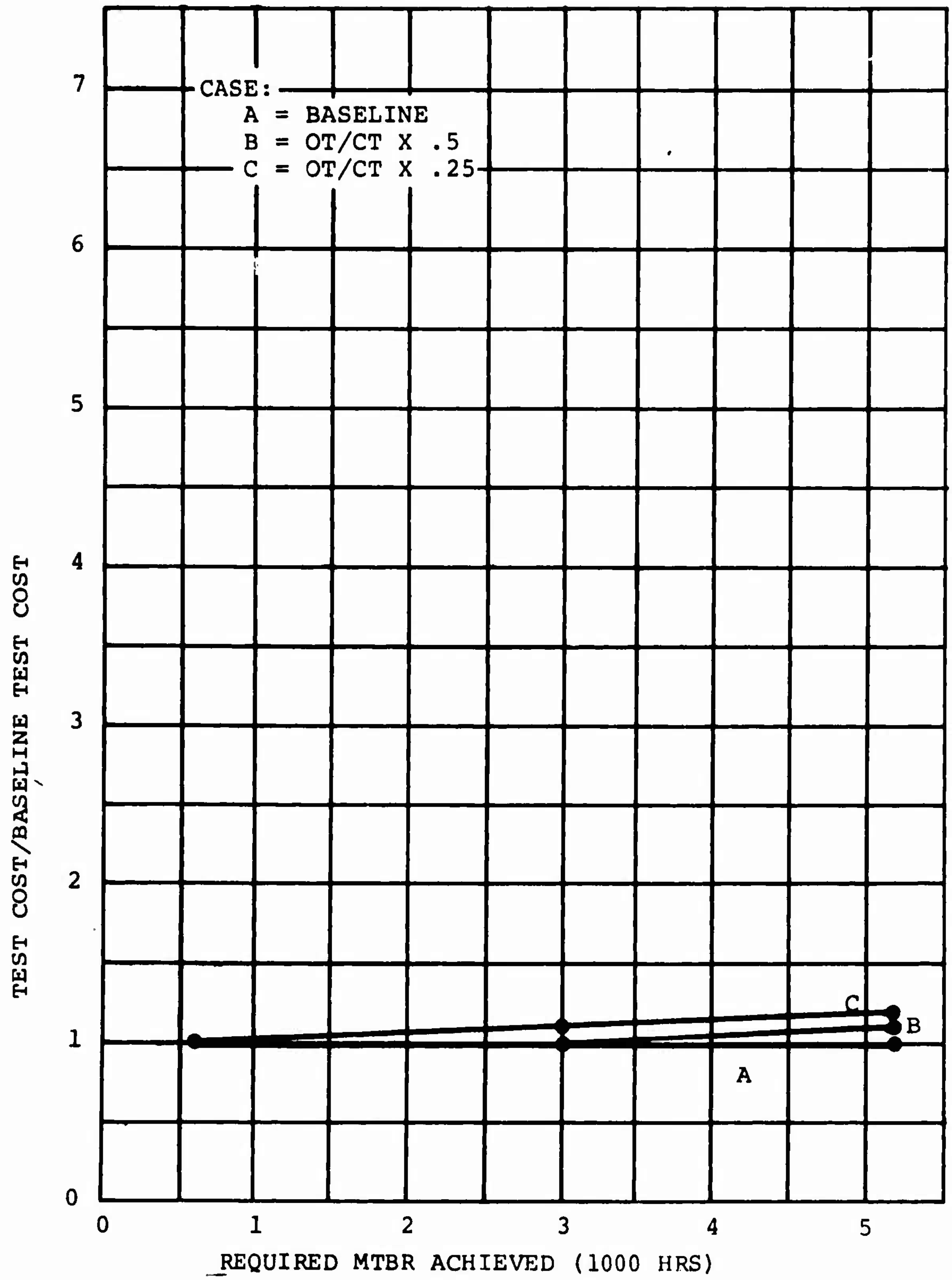

Figure 12. 6-Year Program Operating Time to Calendar Time Sensitivity - Ratio of Study Value and Baseline Value Problem Identification Test Costs.

In most instances, the test operating time/calendar time variable has only a minor effect on problem identification test costs. The one exception is in the 3-year, 25% x OT/CT case. This case suffers from an extremely cramped schedule. The reverse slope of curve C of Figure 10 occurs because of scheduling effects, which is also seen in Figure 25. In the baseline case the higher required MTBR values were already restrained by scheduling, where the lower required MTBR values did not encounter restraints. Escalation of the low MTBR values to a schedule restrained condition resulted in a proportionally greater cost increase.

For the other cases, the flight optimization process compensates for the decrease in test run time. The optimization process permits the bench test hours to be reduced to decrease the requirement for test rigs, while the flight test hours are increased to fill out the testing needed to give the required MTBR. Generally, for the near-optimum values of the cost optimization curve, the bench testing is somewhat inefficient and an hour of flight test can replace several hours of bench testing. This reduces the magnitude of any cost increase.

4.5 SENSITIVITY TO COMBINED VARIABLES

General

The study, until now, deals only with cost sensitivity to single variables. This section of the study identifies the worst case evaluated for each study variable and then combines these individual "worst cases" into a "combined worst case".

The degree of realism for each case of each study variable was tabulated in Section 2.0. Table IV presents a summary for all of the study variables. The individual "worst cases" evaluated for each study variable are identified in Table IV.

The "combined worst case" evaluated represents a situation involving:

- 2 x Baseline Failure Mode Quantity
- Maintenance & Test Criteria Artificial Restraints Present
- 8 Observations to fix, and 1/4 x Baseline Operating Time/Calendar Time Ratio.

"Worst Case" Results

The test programs resulting from the flight test versus bench test cost optimization for the "worst case" analysis are shown in Appendix I.

TABLE IV. SUMMARY OF DEGREES OF REALISM				
	INDIVIDUAL CASES STUDIED			
Degree of Realism	MTBR Off-The-Board	Test Effectiveness	Corrective Action Efficiency	OT/CT
Optimistic, Improbable Case	1/4 x Baseline Failure Mode Quantity	No Restraints	Baseline Efficiency (2 obs. to fix)	Baseline OT/CT Ratios
Expected Case	Baseline Failure Mode Quantity	Baseline Restraints	4 obs. to fix	1/2 x Baseline OT/CT Ratios
Worst Case, Improbable	2 x Baseline Failure Mode Quantity	Maint. & Test Criteria Restraints Added to Baseline Restraints	8 obs. to fix	1/4 x Baseline OT/CT Ratios

The 3-, 4-, and 6-year problem identification individual and combined worst case test program cost plots versus required MTBR achieved are contained in Figures 28, 29, and 30 of Appendix II.

Problem identification program individ[illegible]mbined worst case test costs are summarized in Table V.

Figures 13, 14, and 15 contain plots of worst case costs relative to the associated baseline costs of Volume I versus required MTBR achieved for 3-, 4- and 6-year programs, respectively.

"Worst Case" Discussion

As might be anticipated, the combined worst case analysis shows a drastic increase in test program cost. Program costs escalate 10 to 25 times the baseline cost of Volume I. While a life cycle cost analysis might show the levels of reliability obtained to be cost effective even at these high levels of test program costs, an austere cost environment may nevertheless demand that development program costs be controlled in a direction approaching the Volume I baseline level.

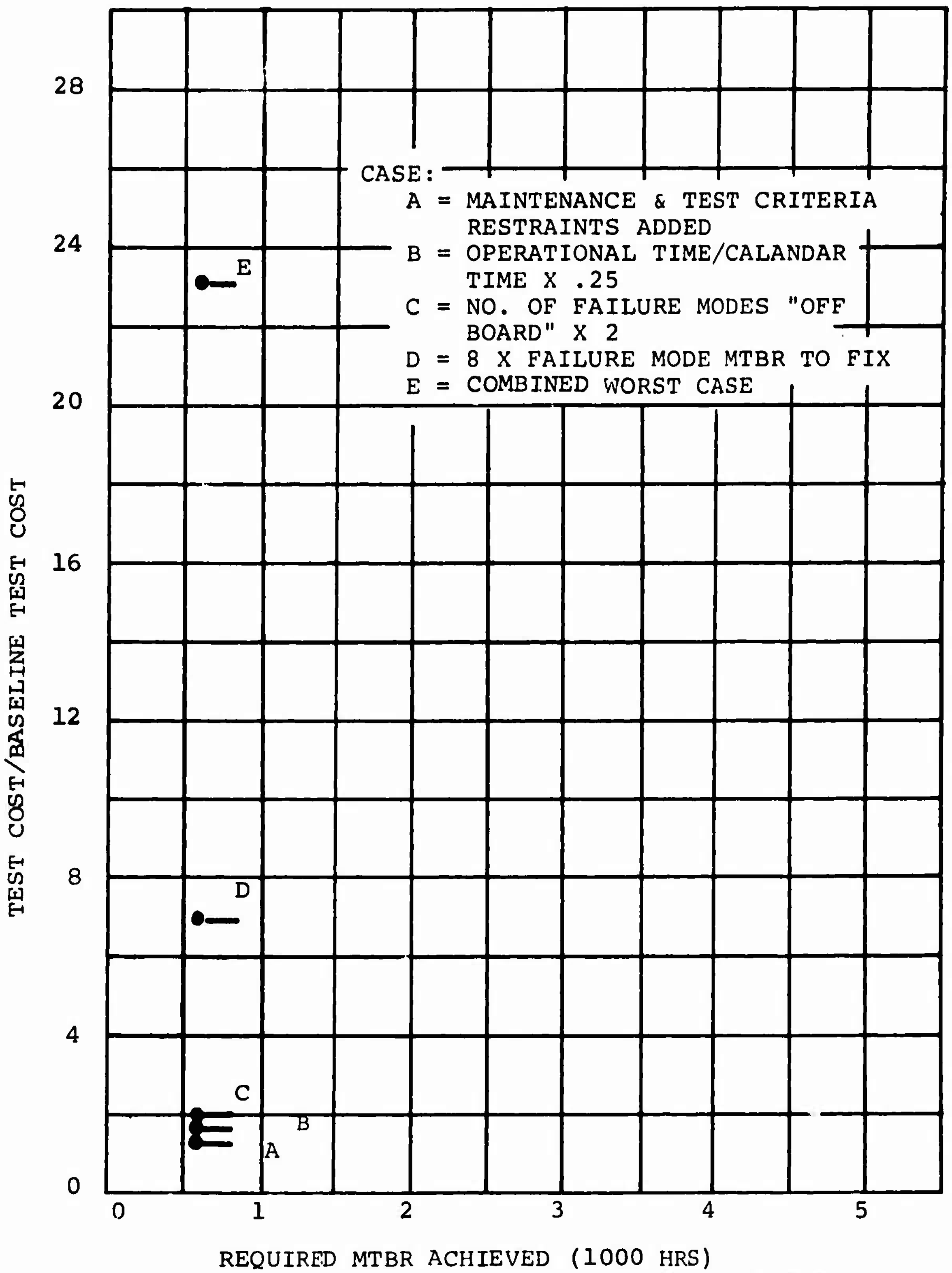

Figure 13. 3-Year Program Worst Cast Anal 'sis - Ratio of Study Value and Baseline Value Problem Identification Test Costs.

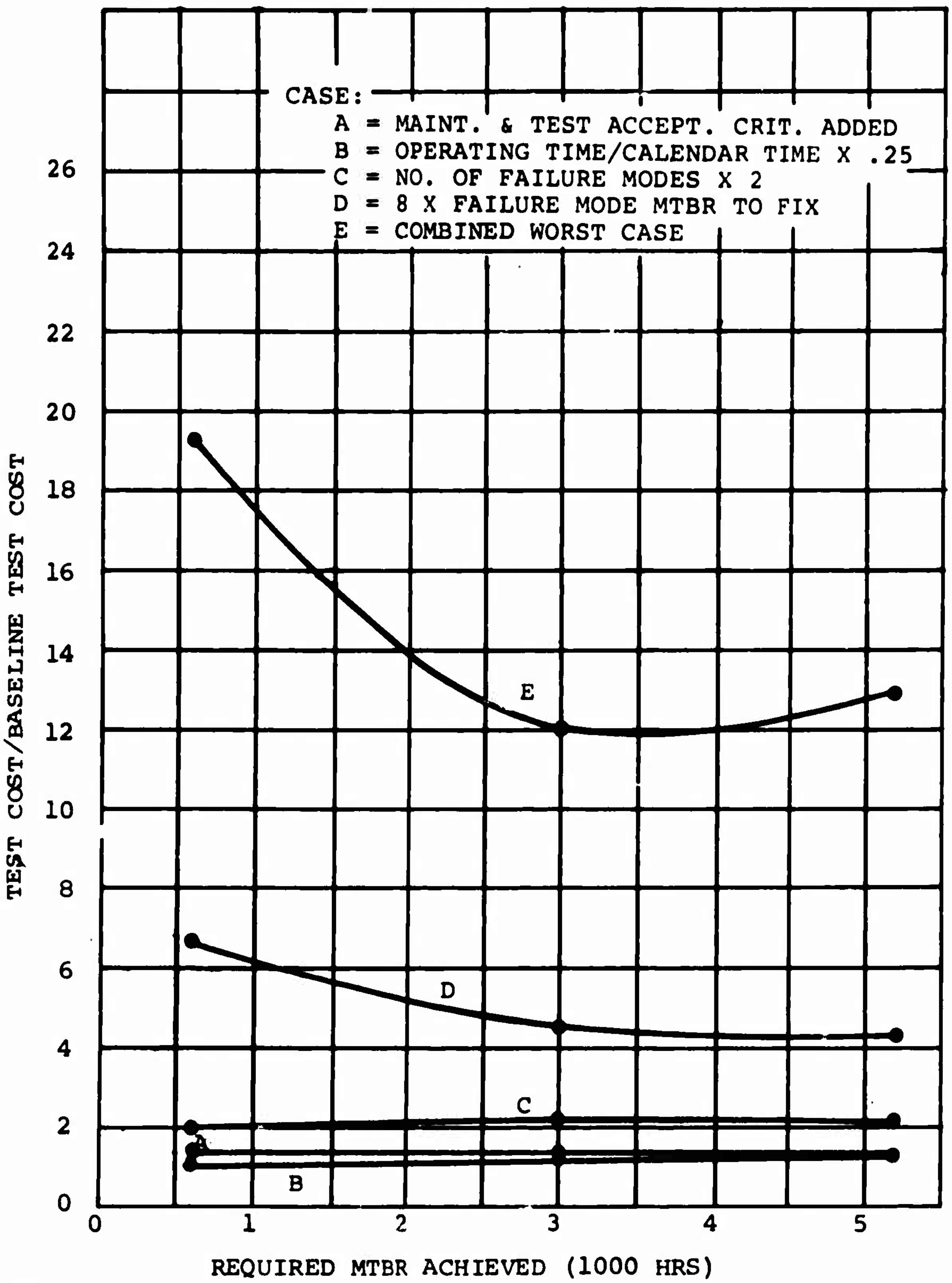

Figure 14. 4-Year Program Worst Case Analysis - Ratio of Study Value and Baseline Value Problem Identification Test Costs.

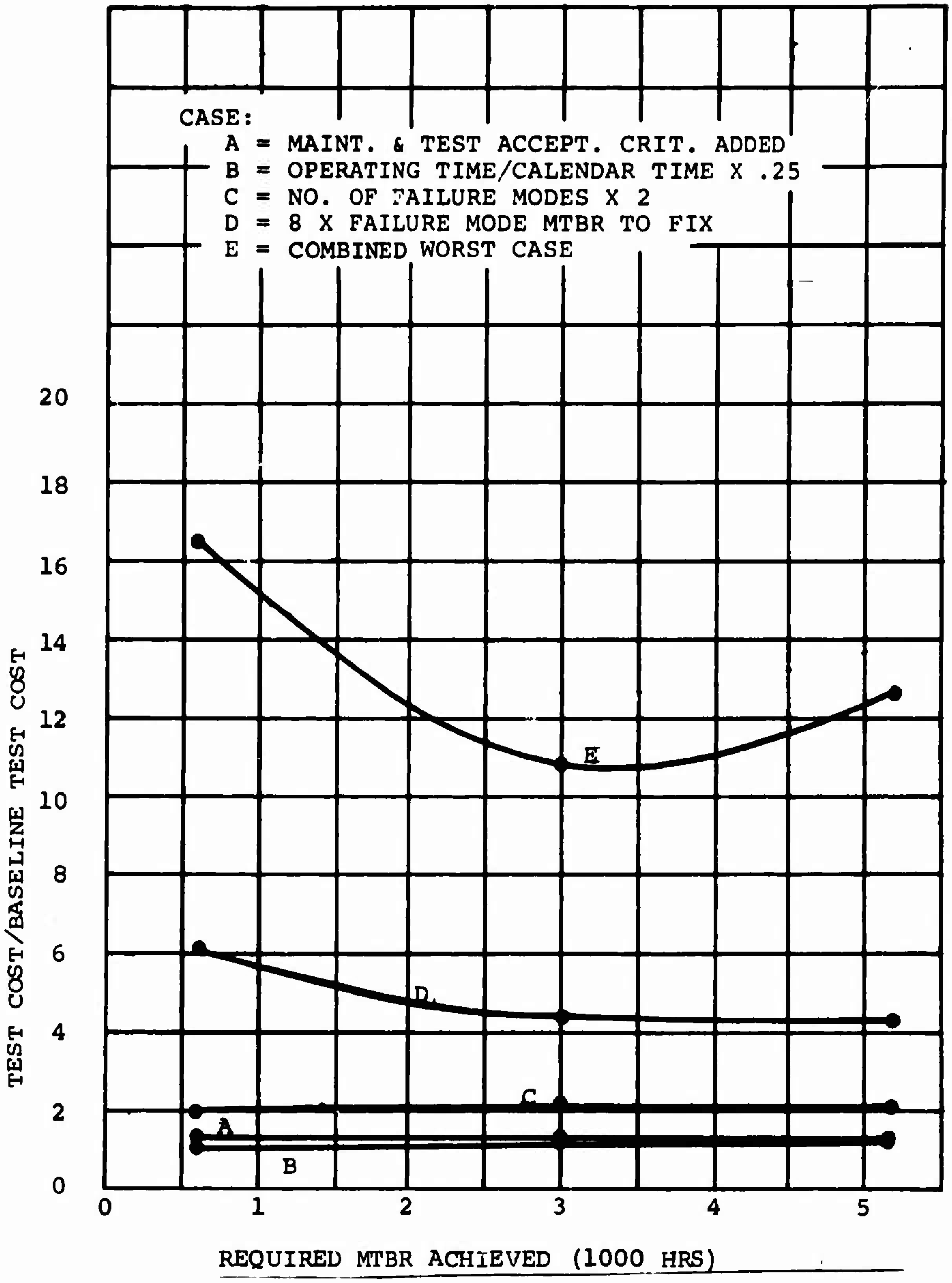

Figure 15. 6-Year Program Worst Case Analysis - Ratio of Study Value and Baseline Value Problem Identification Test Costs.

Significantly, it becomes apparent that an environment must exist that will cause both planning and implementation to occur in the areas of MTBR off-the-board, corrective action efficiency, test effectiveness, and test operating time/calendar time ratio in order that:

- Necessary MTBR's will be achieved.
- Excessive test program costs will be avoided.

5.0 SUMMARY OF RESULTS

Table V presents a summary of the results of this study.

Table VI presents the relative effect of program length on cost.

TABLE V. SUMMARY OF STUDY RESULTS

Case	Req'd MTBR Hours	Program Length: 3 Years Million $	3 Years Rel. Cost	4 Years Million $	4 Years Rel. Cost	6 Years Million $	6 Years Rel. Cost
Baseline	600	2.1	1	2.1	1	2.1	1
	3000	13.8	1	12.5	1	12.5	1
	5200	22.7	1	22.1	1	20.9	1
High-Failure-Rate Modes Removed	600	2.1	1	2.1	1	2.1	1
	3000	13.8	1	12.5	1	12.5	1
	5200	22.7	1	22.1	1	20.9	1
Low-Failure-Rate Modes Removed	600	2.1	1	2.1	1	2.1	1
	3000	9.7	.70	9.4	.75	9.4	.75
	5200	14.8	.65	14.0	.63	13.5	.65
All Failure Modes x 2	600	4.2	2	4.2	2	4.2	2
	3000	28.0	2.03	27.2	2.18	26.1	2.09
	5200	50.7	2.23	46.5	2.10	43.8	2.10
All Failure Modes x 1/4	600	0	0	0	0	0	0
	3000	3.4	.25	3.4	.27	3.4	.27
	5200	6.0	.26	5.1	.23	5.2	.24
4 Observations to Fix	600	5.7	2.71	5.4	2.57	5.4	2.57
	3000	28.6	2.07	26.5	2.12	25.1	2.01
	5200	53.0	2.34	46.4	2.10	45.0	2.15
8 Observations to Fix	600	14.6	6.95	14.0	6.67	12.8	6.10
	3000	63.4	4.59	57.9	4.63	54.4	4.35
	5200	a 193	8.51	93	4.21	90	4.31
Maintenance and Test Acceptance Criteria Restraints Added	600	2.6	1.24	2.6	1.24	2.6	1.24
	3000	17.9	1.30	17.5	1.40	17.5	1.40
	5200	27.5	1.21	26.4	1.20	26.2	1.25
All Restraints Removed (100% Effectiveness)	600	2.0	.95	2.0	.95	2.0	.95
	3000	8.3	.60	6.4	.51	6.4	.51
	5200	11.8	.52	10.6	.48	9.3	.45
.5 x Opr. Time/ Cal. Time Except Flt. Hrs. Not Reduced	600	2.1	1	2.1	1	2.1	1
	3000	15.7	1.14	13.0	1.04	12.5	1
	5200	25.8	1.14	24.1	1.09	23.2	1.11
.25 x Opr. Time/ Cal. Time Except Flt. Hrs. Not Reduced	600	3.4	1.62	2.1	1	2.1	1
	3000	18.5	1.34	16.2	1.30	13.9	1.11
	5200	28.9	1.27	26.3	1.19	25.0	1.20
.5 X Opr. Time/ Cal. Time, Incl. Flt. Hrs.	600	2.1	1	2.1	1	2.1	1
	3000	15.7	1.14	13.0	1.04	12.5	1
	5200	b 39.6	1.74	24.1	1.09	23.2	1.11
.25 X Opr. Time/ Cal. Time Incl Flt. Hrs.	600	3.4	1.62	2.1	1	2.1	1
	3000	b 27.6	2.00	16.2	1.30	13.9	1.11
	5200	c -		26.3	1.19	25.0	1.20
Combined Worst Case	600	48.6	23.14	40.3	19.20	34.7	16.52
	3000	c -	-	144	11.52	118	9.44
	5200	c -	-	305	13.80	264	12.63

NOTES:

a. Controls Do Not Reach Required MTBR
b. Factory Capacity Limits Flight Hrs
c. MTBR Not Attainable

TABLE VI. RELATIVE EFFECT OF PROGRAM LENGTH ON YEAR-TO-YEAR PROGRAM COST VARIATION

Case	Program Length 3-Year	4-Year	6-Year
Baseline	1	1	1
High-Failure-Rate Modes Eliminated	1	1	1
Low-Failure-Rate Modes Eliminated	1	1	1
All Failure Modes x 2	1	1	.99
All Failure Modes x 1/4	1.11	1	1
4 Observations to Fix	1.05	1	.99
8 Observations to Fix	1.29	1	.95
Maint. & Test Accept. Criteria Restraints Added	.98	1	1.01
All Restraints Removed	1.07	1	.98
.5 OT/CT Flight Excluded	1.05	1	
.25 OT/CT Flight Excluded	1.21	1	.95
Worst Case (600 Hrs Req'd MTBR)	1.21	1	.86
Worst Case (3000 or 5200 Hrs Req'd MTBR)	-	1	.87

6.0 CONCLUSIONS

The sensitivity study shows that the numerical reliability requirement/reliability test cost relationship is significantly affected by decisions, philosophy, and approaches taken during the development program with respect to both designing for reliability and subsequent reliability testing.

Contrary to initial expectations, however, the reliability/cost relationships were not uniformly sensitive to each variable under investigation. Specifically, the following was found:

- The test effectiveness and operating time/calendar time variables have only small effects on the problem identification test costs. The flight versus bench test cost optimizations process lets increased flight hours overcome inefficient or reduced bench test at only a small increase in cost.

- MTBR off-the-board directly affects the cost. Where the distribution of problems is equally changed across the frequency spectrum, the cost increase is approximately equal to the percentage of change in the study variable. Flight test efficiency. in these instances is affected the same as bench testing.

  Design reliability analysis and support activities will reduce test costs if the effort is directed toward reducing low- and medium-frequency failure modes. Current attention given to high-frequency problems does little to reduce the test durations or costs.

- Corrective action efficiency is a critical aspect of problem identification costs. Inefficiency can result not only in increased costs but also in failure to achieve the required MTBR (e.g., 50% reduction in contractor corrective action efficiency can result in achieving only 3000 hours MTBR when 5200 hours is required, regardless of the amount spent). The achievement of increased efficiency is dependent, primarily, on the philosophies and controls imposed upon the test and corrective action procedures.

APPENDIX I
SUMMARY OF TEST PROGRAMS

Optimum cost test programs computed for this study are summarized in Table VII. The table contains the test rig run times, the Type II flight times, the number of test rigs, the test rig run cost, the Type II flight test cost, the test rig costs, and the total problem identification test cost for each condition investigated.

TABLE VII. SUMMARY OF TEST PROGRAMS

3-YEAR TEST PROGRAM SUMMARY

Case	Req'd. MTBR Hrs	Type I Flt.Test Time, Thous. Hrs	Type II Flt. Test Time, Thous. Hrs	Type II Flt. Test Cost, Mill. Doll.	Closed Loop Main XMSN Test Stand Test Time, Thous. Hrs	Closed Loop Main XMSN Test Stand Run Cost, Mill. Doll.	Closed Loop Main XMSN Test Stand No. of Test Stands	Closed Loop Main XMSN Test Stand Stand Cost, Mill. Doll.	Closed Loop Main XMSN Test Stand Test Cost, Mill. Doll.	Whirl Tower Test Time, Thous. Hrs	Whirl Tower Run Cost, Mill. Doll.	Whirl Tower No. of Test Stands	Whirl Tower Stand Cost, Mill. Doll.	Whirl Tower Test Cost, Mill. Doll.	Tes Tim Tho Hrs
Baseline	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	.
	3000	1.5	2.2	5.5	12.0	3.36	2	2.6	5.96	3.4	.75	1	.56	1.3	7.
	5200	1.5	6.0	15.0	14.4	4.03	2	2.6	6.6	1.8	.40	1	.56	1.0	1.
High failure rate modes removed	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	.
	3000	1.5	2.2	5.5	12.0	3.36	2	2.6	5.96	3.4	.75	1	.56	1.31	7.
	5200	1.5	6.0	15.0	14.4	4.03	2	2.6	6.63	1.8	.4	1	.56	.96	1.
Low failure rate modes removed	600	1.5	0	0	2.7	.7	1	1.3	2.0	0	0	0	0	0	.
	3000	1.5	1.7	4.2	7.2	2.0	1	1.3	3.3	2.8	.62	1	.56	1.18	3.
	5200	1.5	2.2	5.5	12.9	3.6	2	2.6	6.2	5.2	1.1	1	.56	1.66	10.
All failure modes X 2	600	1.5	0	0	6.8	1.9	1	1.3	3.2	0	0	0	0	0	4.
	3000	1.5	8.5	21.2	14.4	4.0	2	2.6	6.6	0	0	0	0	0	.
	5200	1.5	8.5	21.2	56.7	15.9	8	10.4	26.3	5.5	1.2	1	.56	1.76	4.
All failure modes X 1/4	600	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0
	3000	1.5	0	0	5.2	1.5	1	1.3	2.8	0	0	0	0	0	2.
	5200	1.5	.7	1.8	7.2	2	1	1.3	3.3	0	0	0	0	0	4
4 observations to fix	600	1.5	.7	1.8	7.2	2	1	1.3	3.3	0	0	0	0	0	3.
	3000	1.5	5.6	14.0	20.6	5.8	3	3.9	9.7	7.5	1.6	2	1.12	1.7	2.
	5200	1.5	10.3	25.8	57.0	16.0	5	6.5	22.5	10.3	2.3	2	1.12	3.4	7.
8 observations to fix	600	1.5	2.8	7.0	14.4	4.0	2	2.6	6.6	0	0	0	0	0	7.
	3000	1.5	10.3	25.8	52.1	14.6	8	10.4	25.0	17.0	3.7	3	3.7	7.4	80.
	5200*	1.5	10.3	25.8	26.6	74.5	38	49.4	123.9	33.7	8.5	7	14.1	22.6	21.
	5200**	1.5	27.5	68.8	57	16	8	10.4	26.4	11.2	2.5	2	1.12	3.6	6.
Maintenance and test acceptance criteria added	600	1.5	0	0	4.2	1.2	1	1.3	2.5	0	0	0	0	0	1.
	3000	1.5	5.8	14.5	7.2	2.0	1	1.3	3.3	0	0	0	0	0	.
	5200	1.5	8.3	20.8	14.4	4.0	2	2.6	6.6	0	0	0	0	0	.
All restraints removed (100% effectiveness)	600	1.5	0	0	2.0	.56	1	1.3	1.9	0	0	0	0	0	1.
	3000	1.5	0	0	9.0	2.5	2	2.6	5.1	5.0	1.1	2	1.12	1.2	2.
	5200	1.5	0	0	14.0	3.9	3	3.9	7.8	7.5	1.65	2	1.12	1.8	0
.5 X operating time/cal. time except flt. hrs. not reduced	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	.85
	3000	1.5	2.9	7.2	9.3	2.6	3	3.9	6.5	2.8	.62	1	.56	1.2	2.
	5200	1.5	7.2	18.0	10.8	3.02	3	3.9	6.9	.6	.13	1	.56	.7	1.
.5 X operating time/cal. time including flt. hrs.	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	.
	3000	1.5	2.9	7.2	9.3	2.6	3	3.9	6.5	2.8	.62	1	.56	1.2	2.
	5200	1.5	4.5	11.2	39.5	11.06	11	14.3	25.4	4.3	.95	2	1.12	2.1	3.
.25 X operating time/cal. time excluding flt. hrs.	600	1.5	.6	1.5	1.8	.5	1	1.3	1.8	0	0	0	0	0	.
	3000	1.5	4.9	12.2	5.4	1.5	3	3.9	5.4	.11	1.0	1	.56	1.6	.
	5200	1.5	CAN'T	OBTAIN											
.25 X operating time/cal. time including flt. hrs.	600	1.5	.6	1.5	1.8	.5	1	1.3	1.8	0	0	0	0	0	.
	3000	1.5	1.5	3.8	13.3	3.7	8	10.4	23.7	4.4	.97	4	6.3	7.3	13.7
	5200	1.5	CAN'T	OBTAIN											
Combined worst case	600	1.5	8.5	21.2	23.5	6.6	14	18.2	24.8	0	0	0	0	0	12.1
	3000	1.5	CAN'T	OBTAIN											
	5200	1.5	CAN'T	OBTAIN											

* Flt. controls cannot reach required MTBR - Flt. hrs. are limited at factory capacity.
** Restriction of factory limit deleted.

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SUMMARY OF TEST PROGRAMS

3-YEAR TEST PROGRAM SUMMARY

Whirl Tower				Controls Bench Test Stand					Tail Rotor Test Stand							
Run Cost, Mill. Doll.	No. of Test Stands	Stand Cost, Mill. Doll.	Test Cost, Mill. Doll.	Test Time, Thous. Hrs	Run Cost, Mill. Doll.	No. of Test Stands	Stand Cost, Mill. Doll.	Test Cost, Mill. Doll.	Test Time, Thous. Hrs	Run Cost, Mill. Doll.	No. of Test Stands	Stand Cost, Mill. Doll.	Test Cost, Mill. Doll.	Total Run Cost, Mill. Doll.	Total Acq. Cost, Mill. Doll.	Total Prog. Cost, Mill. Doll.
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.75	1	.56	1.3	7.2	.29	1	.1	.39	2.8	.31	1	.33	1.0	10.2	3.6	13.8
.40	1	.56	1.0	1.4	.06	1	.1	.16	0	0	0	0	0	19.5	3.2	22.7
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.75	1	.56	1.31	7.2	.29	1	.1	.39	2.8	.31	1	.33	1.0	10.2	3.6	13.8
.4	1	.56	.96	1.4	.06	1	.1	.16	0	0	0	0	0	19.5	3.2	22.7
0	0	0	0	.6	.02	1	.1	.13	0	0	0	0	0	.69	1.4	2.1
.62	1	.56	1.18	3.4	.14	1	.1	.24	3.25	.36	1	.33	.69	7.4	2.3	9.7
1.1	1	.56	1.66	10.1	.4	1	.1	.5	5.3	.58	1	.33	.91	11.2	3.6	14.8
0	0	0	0	4.6	.18	1	.1	.28	3.5	.38	1	.33	.71	2.4	1.8	4.2
0	0	0	0	.3	.01	1	.1	.11	0	0	0	0	0	25.3	2.7	28.0
1.2	1	.56	1.76	4.5	.18	1	.1	.28	6.8	.75	1	.33	1.08	39.2	11.5	50.7
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	2.7	.11	1	.1	.21	.8	.09	1	.33	.42	1.7	1.7	3.4
0	0	0	0	4	.16	1	.1	.26	2.9	.32	1	.33	.65	4.2	1.8	6.0
0	0	0	0	3.5	.14	1	.1	.24	.5	.06	1	.33	.39	4.6	1.7	5.7
1.6	2	1.12	1.7	2.0	.8	2	.2	1.0	8.0	.88	1	.33	1.2	23.0	5.6	28.6
2.3	2	1.12	3.4	7.0	.28	1	.1	.38	7.2	.79	1	.33	1.1	45.0	8.0	53.0
0	0	0	0	7.2	.29	1	.1	.39	1.4	.15	1	.33	.48	11.6	3.0	14.6
3.7	3	3.7	7.4	80.0	3.4	5	.5	3.9	18.1	2.0	3	.99	3.0	51.5	15.6	67.1
8.5	7	14.1	22.6	21.0	.84	2	.2	1.0	72.2	7.9	9	3.0	10.9	125	68	193*
2.5	2	1.12	3.6	6.0	.24	1	.1	.34	5.2	.57	1	.33	.9	88.1	11.9	100**
0	0	0	0	1.0	.04	1	.1	.14	0	0	0	0	0	1.2	1.4	2.6
0	0	0	0	.3	.01	1	.1	.11	0	0	0	0	0	16.5	1.4	17.9
0	0	0	0	.6	.02	1	.1	.12	0	0	0	0	0	24.8	2.7	27.5
0	0	0	0	1.0	.038	1	.1	.14	0	0	0	0	0	.6	1.4	2.0
1.1	2	1.12	1.2	2.5	.1	1	.1	.2	3.5	.39	1	.33	.7	4.2	4.1	8.3
1.65	2	1.12	1.8	0	0	0	0	0	5.5	.605	1	.33	.9	6.5	5.3	11.8
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.62	1	.56	1.2	2.0	.08	1	.1	.18	2.5	.28	1	.33	.6	10.8	4.9	15.7
.13	1	.56	.7	1.4	.06	1	.1	.16	0	0	0	0	0	21.2	4.6	25.8
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.62	1	.56	1.2	2.0	.08	1	.1	.18	2.5	.28	1	.33	.6	10.8	4.9	15.7
.95	2	1.12	2.1	3.0	.12	1	.1	.22	3.1	.34	1	.33	.67	23.7	15.9	39.6
0	0	0	0	.1	0	1	.1	.1	0	0	0	0	0	2.0	1.4	3.4
1.0	1	.56	1.6	.04	0	1	.1	.1	0	0	0	0	0	13.9	4.6	18.5
0	0	0	0	.1	0	1	.1	.1	0	0	0	0	0	2.0	1.4	3.4
.97	4	6.3	7.3	13.7	.54	4	.4	.9	4.9	.54	3	.99	1.5	9.5	18.1	27.6
0	0	0	0	12.1	.48	4	.4	12.5	5.5	.61	3	.99	1.6	29.0	17.6	48.6

TABLE VII - (Cont.)

4-YEAR TEST PROGRAM SUMMARY

	Req'd. MTBR Hrs	Type I Flt. Test Time, Thous. Hrs	Type II Flt. Test: Time, Thous. Hrs	Type II Flt. Test: Cost, Mill. Dol.	Closed Loop Main XMSN Test Stand: Test Time, Thous. Hrs	Closed Loop Main XMSN Test Stand: Run Cost, Mill. Doll.	Closed Loop Main XMSN Test Stand: No. of Test Stands	Closed Loop Main XMSN Test Stand: Stand Cost, Mill. Doll.	Closed Loop Main XMSN Test Stand: Test Cost, Mill. Doll.	Whirl Tower: Test Time, Thous. Hrs	Whirl Tower: Run Cost, Mill. Doll.	Whirl Tower: No. of Test Stands	Whirl Tower: Stand Cost, Mill. Doll.	Whirl Tower: Test Cost, Mill. Doll.	Test Time, Thous. Hrs
line	600	1.5	0	0	2.5	7	1	1.3	2.0	0	0	0	0	0	.85
	3000	1.5	2.2	5.5	12	3.36	1	1.3	4.7	3.4	.75	1	.56	1.3	7.2
	5200	1.5	4.5	11.2	22.6	6.05	2	2.6	8.6	4.2	.92	1	.56	1.5	2.15
failure rate es removed	600	1.5	0	0	2.35	.66	1	1.3	2.0	0	0	0	0	0	.8
	3000	1.5	2.2	5.5	12	3.36	1	1.3	4.7	3.4	7.5	1	.56	1.3	7.2
	5200	1.5	4.5	11.2	22.6	6.05	2	2.6	8.6	4.2	.92	1	.56	1.5	2.15
failure rate es removed	600	1.5	0	0	2.7	.7	1	1.3	2.0	0	0	0	0	0	.6
	3000	1.5	1.5	3.8	7.6	2.2	1	1.3	3.5	3.0	.66	1	.56	1.22	4.3
	5200	1.5	2.7	6.8	11.9	3.3	1	1.3	4.7	4.6	1.0	1	.56	1.5	5.0
failure modes	600	1.5	0	0	6.8	1.9	1	1.3	3.2	0	0	0	0	0	4.6
	3000	1.5	7.3	18.2	19.5	5.5	2	2.6	8.1	1.4	.31	1	.56	.87	.7
	5200	1.5	7.9	19.8	60	16.8	5	6.5	23.3	6.1	1.3	1	.56	1.86	4.9
failure modes /4	600	1.5	0	0	0	0	0	0	0	0	0	0	0	0	0
	3000	1.5	0	0	5.2	1.5	1	1.3	2.8	0	0	0	0	0	2.7
	5200	1.5	0	0	9.7	2.7	1	1.3	4.0	0	0	0	0	0	5.6
servations fix	600	1.5	.5	1.2	7.8	2.2	1	1.3	3.5	0	0	0	0	0	3.9
	3000	1.5	5.5	13.8	20.8	5.8	2	2.6	8.4	7.7	1.7	1	.56	2.3	21
	5200	1.5	11.5	28.8	36.0	10.1	3	3.9	14.0	8.7	1.9	1	.56	1.5	4.0
servations fix	600	1.5	3.6	1.0	11.7	3.3	1	1.3	4.6	0	0	0	0	0	5.8
	3000	1.5	19.5	26.2	51.5	14.4	5	6.5	20.9	16.8	3.7	2	1.12	4.8	74.0
	5200*	1.5	22.7	56.8	75.5	21.1	6	7.8	28.9	18.2	4.0	2	1.12	5.1	13.0
tenance and acceptance teria added	600	1.5	0	0	4.2	1.2	1	1.3	2.5	0	0	0	0	0	1.0
	3000	1.5	5.3	13.2	10	2.9	1	1.3	4.1	0	0	0	0	0	1.0
	5200	1.5	8.7	21.8	12.0	3.4	1	1.3	4.7	0	0	0	0	0	0
restraints oved (100% ctiveness)	600	1.5	0	0	2.0	.56	1	1.3	1.9	0	0	0	0	0	1.0
	3000	1.5	0	0	9.0	2.5	1	1.3	3.8	5.0	1.1	1	.56	1.7	2.5
	5200	1.5	0	0	14.0	3.9	2	2.6	6.5	7.5	1.65	1	.56	2.2	0
operating /cal. time pt flt. hrs. reduced	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	.85
	3000	1.5	2.0	5.0	11.7	3.3	2	2.6	5.9	3.9	.86	1	.56	1.42	5.1
	5200	1.5	6.9	17.2	12.0	3.36	2	2.6	5.96	.9	.2	1	.56	.76	1.5
operating /cal. time uding flt.	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	.85
	3000	1.5	2.0	5.0	11.7	3.3	2	2.6	5.9	3.9	.86	1	.56	1.42	5.1
	5200	1.5	6.9	17.2	12.0	3.36	2	2.6	5.96	.9	.2	1	.56	.76	1.5
operating /cal. time uding flt.	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	.85
	3000	1.5	3.2	8.0	8.7	2.4	3	3.9	6.3	2.4	.54	1	.56	1.1	1.8
	5200	1.5	7.9	19.8	9.0	2.5	3	3.9	6.4	0	0	0	0	0	1.1
operating /cal. time uding flt.	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	.85
	3000	1.5	3.2	8.0	8.7	2.4	3	3.9	6.3	2.4	.54	1	.56	1.1	1.8
	5200	1.5	7.9	19.8	9.0	2.5	3	3.9	6.4	0	0	0	0	0	1.1
ned worst	600	1.5	8.5	21.2	23.5	6.6	8	10.4	17.0	0	0	0	0	0	12.1
	3000	1.5	43.5	108.2	4.8	13	17	22.1	35.1	0	0	0	0	0	0
	5200	1.5	58.5	146.2	5	60	72	97	157	6	1.3	3	2.2	3.5	3

lt. controls cannot reach required MTBR - Flt. hrs. are limited at factory capacity.
estriction of factory limit deleted.

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TABLE VII - (Cont.)

4-YEAR TEST PROGRAM SUMMA[RY]

Case	Req'd. MTBR Hrs	Type I Flt. Test Time, Thous. Hrs	Type II Flt. Test Time, Thous. Hrs	Type II Flt. Test Cost, Mill. Doll.	Closed Loop Main XMSN Test Stand Test Time, Thous. Hrs	Closed Loop Main XMSN Test Stand Run Cost, Mill. Doll.	Closed Loop Main XMSN Test Stand No. of Test Stands	Closed Loop Main XMSN Test Stand Stand Cost, Mill. Doll.	Closed Loop Main XMSN Test Stand Test Cost, Mill. Doll.	Whirl Tower Test Time, Thous. Hrs	Whirl Tower Run Cost, Mill. Doll.	Whirl Tower No. of Test Stands	Whirl Tower Stand Cost, Mill. Doll.	Whirl Tower Tes[t] Cos[t] Mil[l]. Dol[l].
Baseline	600	1.5	0	0	2.5	7	1	1.3	2.0	0	0	0	0	0
	3000	1.5	2.2	5.5	12	3.36	1	1.3	4.7	3.4	.75	1	.56	1.
	5200	1.5	4.5	11.2	22.6	6.05	2	2.6	8.6	4.2	.92	1	.56	1.
High failure rate modes removed	600	1.5	0	0	2.35	.66	1	1.3	2.0	0	0	0	0	0
	3000	1.5	2.2	5.5	12	3.36	1	1.3	4.7	3.4	7.5	1	.56	1
	5200	1.5	4.5	11.2	22.6	6.05	2	2.6	8.6	4.2	.92	1	.56	1
Low failure rate modes removed	600	1.5	0	0	2.7	.7	1	1.3	2.0	0	0	0	0	0
	3000	1.5	1.5	3.8	7.6	2.2	1	1.3	3.5	3.0	.66	1	.56	1
	5200	1.5	2.7	6.8	11.9	3.3	1	1.3	4.7	4.6	1.0	1	.56	1
All failure modes X 2	600	1.5	0	0	6.8	1.9	1	1.3	3.2	0	0	0	0	0
	3000	1.5	7.3	18.2	19.5	5.5	2	2.6	8.1	1.4	.31	1	.56	
	5200	1.5	7.9	19.8	60	16.8	5	6.5	23.3	6.1	1.3	1	.56	1
All failure modes X 1/4	600	1.5	0	0	0	0	0	0	0	0	0	0	0	0
	3000	1.5	0	0	5.2	1.5	1	1.3	2.8	0	0	0	0	0
	5200	1.5	0	0	9.7	2.7	1	1.3	4.0	0	0	0	0	0
4 observations to fix	600	1.5	.5	1.2	7.8	2.2	1	1.3	3.5	0	0	0	0	0
	3000	1.5	5.5	13.8	20.8	5.8	2	2.6	8.4	7.7	1.7	1	.56	2
	5200	1.5	11.5	28.8	36.0	10.1	3	3.9	14.0	9.7	1.9	1	.56	1
8 observations to fix	600	1.5	4.6	1.0	11.7	3.3	1	1.3	4.6	0	0	0	0	0
	3000	1.5	10.5	26.2	51.5	14.4	5	6.5	20.9	16.8	3.7	2	1.12	4
	5200*	1.5	22.7	56.8	75.5	21.1	6	7.8	28.9	18.3	4.0	2	1.12	[illegible]
Maintenance and test acceptance criteria added	600	1.5	0	0	4.2	1.2	1	1.3	2.5	0	0	0	0	[illegible]
	3000	1.5	5.3	13.2	10	2.9	1	1.3	4.1	0	0	0	0	[illegible]
	5200	1.5	8.7	21.8	12.0	3.4	1	1.3	4.7	0	0	0	0	[illegible]
All restraints removed (100% effectiveness)	600	1.5	0	0	2.0	.56	1	1.3	1.9	0	0	0	0	[illegible]
	3000	1.5	0	0	9.0	2.5	1	1.3	3.8	5.0	1.1	1	.56	[illegible]
	5200	1.5	0	0	14.0	3.9	2	2.6	6.5	7.5	1.65	1	.56	[illegible]
.5 X operating time/cal. time except flt. hrs. not reduced	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	[illegible]
	3000	1.5	2.0	5.0	11.7	3.3	2	2.6	5.9	3.9	.86	1	.56	
	5200	1.5	6.9	17.2	12.0	3.36	2	2.6	5.96	.9	.2	1	.56	
.5 X operating time/cal. time including flt. hrs.	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	
	3000	1.5	2.0	5.0	11.7	3.3	2	2.6	5.9	3.9	.86	1	.56	
	5200	1.5	6.9	17.2	12.0	3.36	2	2.6	5.96	.9	.2	1	.56	
.25 X operating time/cal. time excluding flt. hrs.	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	
	3000	1.5	3.2	8.0	8.7	2.4	3	3.9	6.3	2.4	.54	1	.56	
	5200	1.5	7.9	19.8	9.0	2.5	3	3.9	6.4	0	0	0	0	
.25 X operating time/cal. time including flt. hrs.	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	
	3000	1.5	3.2	8.0	8.7	2.4	3	3.9	6.3	2.4	.54	1	.56	
	5200	1.5	7.9	19.8	9.0	2.5	3	3.9	6.4	0	0	0	0	
Combined worst case	600	1.5	8.5	21.2	23.5	6.6	8	10.4	17.0	0	0	0	0	
	3000	1.5	43.5	108.2	4.8	13	17	22.1	35.1	0	0	0	0	
	5200	1.5	58.5	146.2	215	60	72	97	157	6	1.3	2	2.2	

* Flt. controls cannot reach required MTBR - Flt. hrs. are limited at factory capacity.
** Restriction of factory limit deleted.

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TABLE VII - (Cont.)

4-YEAR TEST PROGRAM SUMMARY																
Whirl Tower				Controls Bench Test Stand					Tail Rotor Test Stand					Total Run Cost, Mill. Doll.	Total Acq. Cost, Mill. Doll.	Total Prog. Cost, Mill. Doll.
Run Cost, Mill. Doll.	No. of Test Stands	Stand Cost, Mill. Doll.	Test Cost, Mill. Doll.	Test Time, Thous. Hrs	Run Cost, Mill. Doll.	No. of Test Stands	Stand Cost, Mill. Doll.	Test Cost, Mill. Doll.	Test Time, Thous. Hrs	Run Cost, Mill. Doll.	No. of Test Stands	Stand Cost, Mill. Doll.	Test Cost, Mill. Doll.			
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.75	1	.56	1.3	7.2	.29	1	.1	.39	2.8	.31	1	.33	.6	10.2	2.3	12.5
.92	1	.56	1.5	2.15	.09	1	.1	.19	1.9	.21	1	.33	.54	18.5	3.6	22.1
0	0	0	0	.8	.03	1	.1	.13	0	0	0	0	0	.69	1.4	2.1
7.5	1	.56	1.3	7.2	.29	1	.1	.39	2.8	.31	1	.33	1.0	10.2	2.3	12.5
.92	1	.56	1.5	2.15	.09	1	.1	.19	1.9	.21	1	.33	.54	18.5	3.6	22.1
0	0	0	0	.6	.02	1	.1	.12	0	0	0	0	0	.7	1.4	2.1
.66	1	.56	1.22	4.3	.17	1	.1	.27	3.5	.38	1	.33	.71	7.1	2.3	9.4
1.0	1	.56	1.5	5.0	.2	1	.1	.19	4.1	.45	1	.33	.54	11.8	2.3	14.1
0	0	0	0	4.6	.18	1	.1	.28	3.5	.38	1	.33	.71	2.4	1.8	4.2
.31	1	.56	.87	.7	.03	1	.1	.13	0	0	0	0	0	24.0	3.2	27.2
1.3	1	.56	1.86	4.9	.20	1	.1	.30	8.0	.88	1	.33	1.21	39.0	7.5	46.5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	2.7	.11	1	.1	.21	.8	.09	1	.33	.42	1.7	1.7	3.4
0	0	0	0	5.6	.22	1	.1	.32	3.8	.42	1	.33	.75	3.4	1.7	5.1
0	0	0	0	3.9	.16	1	.1	.26	.8	.09	1	.33	.42	3.7	1.7	5.4
1.7	1	.56	2.3	21	.84	1	.1	.94	8.1	.89	1	.33	1.22	22.9	3.6	26.5
1.9	1	.56	1.5	4.0	.16	1	.1	.26	5.1	.56	1	.33	.89	41.4	5.0	46.4
0	0	0	0	5.8	.23	1	.1	.33	0	0	0	0	0	12.6	1.4	14.0
3.7	2	1.12	4.8	74.0	3.0	4	.4	3.4	17.8	2.0	2	.66	2.7	49.2	8.7	57.9
4.0	2	1.12	5.1	13.0	.52	1	.1	.42	11.8	1.3	1	.33	1.6	83.8	9.2	93.0
0	0	0	0	1.0	.04	1	.1	.14	0	0	0	0	0	1.2	1.4	2.6
0	0	0	0	1.0	.04	1	.1	.14	0	0	0	0	0	16.1	1.4	17.5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	25.1	1.3	26.4
0	0	0	0	1.0	.04	1	.1	.14	0	0	0	0	0	.6	1.4	2.0
1.1	1	.56	1.7	2.5	.1	1	.1	.2	3.5	.39	1	.33	.7	3.6	2.8	6.4
1.65	1	.56	2.2	0	0	0	0	0	5.5	.6	1	.33	.9	6.5	4.0	10.5
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.86	1	.56	1.42	5.1	.20	1	.1	.30	4	.44	1	.33	.77	9.8	3.6	13.4
.2	1	.56	.76	1.5	.06	1	.1	.16	0	0	0	0	0	20.8	3.3	24.1
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.86	1	.56	1.42	5.1	.2	1	.1	.3	4	.44	1	.33	.77	9.8	3.6	13.4
.2	1	.56	.76	1.5	.06	1	.1	.16	0	0	0	0	0	20.8	3.3	24.1
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.54	1	.56	1.1	1.8	.07	1	.1	.17	2	.22	1	.33	.55	11.3	4.9	16.2
0	0	0	0	1.1	.04	1	.1	.14	0	0	0	0	0	22.3	4.0	26.3
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.54	1	.56	1.1	1.8	.07	1	.1	.17	2	.22	1	.33	.55	11.3	4.9	16.2
0	0	0	0	1.1	.04	1	.1	.14	0	0	0	0	0	22.3	4.0	26.3
0	0	0	0	12.1	.48	3	.3	.78	5.5	.61	2	.66	1.27	29.0	11.3	40.3
0	0	0	0	0	0	0	0	0	0	0	0	0	0	122.2	22.1	144
1.3	3	2.2	3.5	3	.12	1	.1	.22	0	0	0	0	0	208	97	305

TABLE VII - (Cont.)

6-YEAR TEST PROGRAM SUMMARY

Case	Req'd. MTBR Hrs	Type I Flt. Test Time, Thous. Hrs	Type II Flt. Test: Time, Thous. Hrs	Type II Flt. Test: Cost, Mill. Doll.	Closed Loop Main XMSN Test Stand: Test Time, Thous. Hrs	Closed Loop Main XMSN Test Stand: Run Cost, Mill. Doll.	Closed Loop Main XMSN Test Stand: No. of Test Stands	Closed Loop Main XMSN Test Stand: Stand Cost, Mill. Doll.	Closed Loop Main XMSN Test Stand: Test Cost, Mill. Doll.	Whirl Tower: Test Time, Thous. Hrs	Whirl Tower: Run Cost, Mill. Doll.	Whirl Tower: No. of Test Stands	Whirl Tower: Stand Cost, Mill. Doll.	Whirl Tower: Test Cost, Mill. Doll.	Te Ti Th Hr
Baseline	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	
	3000	1.5	2.2	5.5	12.0	3.4	1	1.3	4.7	3.4	.75	1	.56	1.3	7
	5200	1.5	4.5	11.2	22.6	6.05	1	1.3	7.3	4.2	.92	1	.56	1.5	2
High failure rate modes removed	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	
	3000	1.5	2.2	5.5	12.0	3.4	1	1.3	4.7	3.4	.75	1	.56	1.3	7
	5200	1.5	4.5	11 2	22.6	6.0	1	1.3	7.3	4.2	.92	1	.56	1.5	2
Low failure rate modes removed	600	1.5	0	0	2.7	.7	1	1.3	2.0	0	0	0	0	0	
	3000	1.5	1.5	3.8	7.6	2.2	1	1.3	3.5	3.0	.66	1	.56	1.22	4
	5200	1.5	2.2	5.5	12.9	3.6	1	1.3	4.9	5.2	1.1	1	.56	1.66	10
All failure modes X 2	600	1.5	0	0	6.8	1.9	1	1.3	3.2	0	0	0	0	0	4
	3000	1.5	7.3	18.2	19.5	5.5	1	1.3	6.8	1.4	.31	1	.56	.87	
	5200	1.5	7.5	18.8	62.0	17.4	3	3.9	21.3	7.0	1.5	1	.56	2.1	5
All failure modes X 1/4	600	1.5	0	0	0	0	0	0	0	0	0		0	0	(
	3000	1.5	0	0	5.2	1.5	1	1.3	2.8	0	0		0	0	:
	5200	1.5	0	0	9.7	2.7	1	1.3	4.0	0	0		0	0	5
4 observations to fix	600	1.5	.5	1.2	7.8	2.2	1	1.3	3.5		0	0	0	0	:
	3000	1.5	5.0	12.6	21.6	6.0	1	1.3	7.3	8.2	1.9	1	.56	2.4	30
	5200	1.5	11.0	27.4	39.5	11.1	2	2.6	13.7	9.4	2.1	1	.56	2.7	4
8 observations to fix	600	1.5	2.5	6.2	15.5	4.3	1	1.3	5.6	0	0	0	0	0	1
	3000	1.5	10.5	26.2	51.5	14.4	3	3.9	18.3	16.9	3.7	2	.56	4.3	74
	5200	1.5	22.7	56.8	75.5	21.1	4	5.2	26.3	13.3	4.0	1	.56	4.6	1.
Maintenance and test acceptance criteria added	600	1.5	0	0	4.2	1.2	1	1.3	2.5	0	0		0	0	
	3000	1.5	5.3	13.2	10.0	2.8	1	1.3	4.1	0	0	0	0	0	
	5200	1.5	8.3	20.8	14.4	4.[illegible]	1	1.3	5.3	0	0		0	0	
All restraints removed (100% effectiveness)	600	1.5	0	0	2.0	.56	1	1.3	1.9	0	0	0	0	0	
	3000	1.5	0	0	9.0	2.5	1	1.3	5.8	[illegible]	1.2	1	.56	1.7	
	5200	1.5	0	0	14.0	3.9	1	1.3	5.2	7.[illegible]	1.7	1	.56	2.2	(
.5 X operating time/cal. time except flt. hrs. not reduced	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0		0	0	
	3000	1.5	2.5	6.2	10.2	2.9	1	1.3	4.2	3.3	.73	1	.56	1.3	
	5200	1.5	7.2	18.0	10.8	3.02	1	1.3	4.3	.6	.13	1	.56	.7	
.5 X operating time/cal. time including flt. hrs.	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	
	3000	1.5	2.5	6.2	10.2	2.9	1	1.3	4.2	3.3	.73	1	.56	1.3	
	5200	1.5	7.2	18.0	10.8	3.0	1	1.3	4.3	.6	.13	1	.56	.7	
.25 X operating time/cal. time excluding flt. hrs.	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	
	3000	1.5	2.5	6.2	10.2	2.9	2	2.6	5.5	3.3	.73	1	.56	1.3	
	5200	1.5	7.9	19.8	9.0	2.5	2	2.6	5.1	0	0	0	0	0	
.25 X operating time/cal. time including flt. hrs.	600	1.5	0	0	2.5	.7	1	1.3	2.0	0	0	0	0	0	
	3000	1.5	2.5	6.2	10.2	2.9	2	2.6	5.5	3.3	.73	1	.56	1.3	
	5200	1.5	7.9	19.8	9.0	2.5	2	2.6	5.1	0	0	0	0	0	
Combined worst case	600	1.5	7.5	18.8	25.3	7.1	5	6.5	13.6	0	0	0	0	0	1
	3000	1.5	38.5	96.2	70.0	19.6	13	16.9	36.5	3	.61	1	.56	1.2	
	5200	1.5	58.5	146.2	215.0	60.0	40	52.0	267.0	6	1.3	2	1.12	2.4	

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TABLE VII - (Cont.)

6-YEAR TEST PROGRAM SUMMARY

Whirl Tower				Controls Bench Test Stand					Tail Rotor Test Stand					Total	Total	Total
Run Cost, Mill. Doll.	No. of Test Stands	Stand Cost, Mill. Doll.	Test Cost, Mill. Doll.	Test Time, Thous. Hrs	Run Cost, Mill. Doll.	No. of Test Stands	Stand Cost, Mill. Doll.	Test Cost, Mill. Doll.	Test Time, Thous. Hrs	Run Cost, Mill. Doll.	No. of Test Stands	Stand Cost, Mill. Doll.	Test Cost, Mill. Doll.	Run Cost, Mill. Doll.	Acq. Cost, Mill. Doll.	Prog. Cost, Mill. Doll.
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.75	1	.56	1.3	7.2	.29	1	.1	.39	2.8	.31	1	.33	.6	10.2	2.3	12.5
.92	1	.56	1.5	2.2	.09	1	.1	.19	1.9	.21	1	.33	.54	18.5	2.3	20.8
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.75	1	.56	1.3	7.2	.29	1	.1	.39	2.8	.31	1	.33	.6	10.2	2.3	12.5
.92	1	.56	1.5	2.2	.09	1	.1	.19	1.9	.21	1	.33	.54	18.5	2.3	20.8
0	0	0	0	.6	.02	1	.1	.12	0	0	0	0	0	.7	1.4	2.1
.66	1	.56	1.22	4.3	.17	1	.1	.27	3.5	.38	1	.33	.71	7.1	2.3	9.4
1.1	1	.56	1.66	10.1	.4	1	.1	.5	5.3	.58	1	.33	.91	11.2	2.3	13.5
0	0	0	0	4.6	.18	1	.1	.28	3.5	.38	1	.33	.71	2.4	1.8	4.2
.31	1	.56	.87	.7	.03	1	.1	.13	0	0	0	0	0	24.1	2.0	26.1
1.5	1	.56	2.1	5.1	.2	1	.1	.3	8.8	.97	1	.33	1.3	38.8	5.0	43.8
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	2.7	.11	1	.1	.21	.8	.09	1	.33	.42	1.7	1.7	3.4
0	0	0	0	5.6	2.2	1	.1	.32	3.8	.42	1	.33	.75	3.4	1.7	5.1
0	0	0	0	3.9	.16	1	.1	.26	.8	.09	1	.33	.42	3.7	1.7	5.4
1.8	1	.56	2.4	36.4	1.5	1	.1	1.6	8.8	.97	1	.33	1.3	23.0	2.1	25.1
2.1	1	.56	2.7	4.4	.18	1	.1	.28	5.9	.65	1	.33	1.0	41.4	3.6	45.0
0	0	0	0	8.0	.32	1	.1	.42	1.9	.21	1	.33	.5	11.1	1.7	12.8
3.7	1	.56	4.3	74.2	3.0	3	.3	3.3	17.8	2.0	1	.33	2.3	49.2	5.2	54.4
4.0	1	.56	4.6	13.0	.52	1	.1	.62	11.8	1.3	1	.33	1.6	83.[illegible]	6.2	90.0
0	0	0	0	1.0	.04	1	.1	.14	0	0	0	0	0	1.2	1.4	2.6
0	0	0	0	1.0	.04	1	.1	.14	0	0	0	0	0	16.1	1.4	17.5
0	0	0	0	.6	.02	1	.1	.12	0	0	0	0	0	24.8	1.4	26.2
0	0	0	0	1.0	.04	1	.1	.14	0	0	0	0	0	.6	1.4	2.0
1.1	1	.56	1.7	2.5	.1	1	.1	.12	3.5	.39	1	.33	.7	3.6	2.8	6.4
1.7	1	.56	2.2	0	0	0	0	0	5.5	.6	1	.33	.9	6.5	2.8	9.3
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.73	1	.56	1.3	2.9	.12	1	.1	.22	3.1	.34	1	.33	.7	10.2	2.3	12.5
.13	1	.56	.7	1.4	.06	1	.1	.16	0	0	0	0	0	21.2	2.0	23.2
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.73	1	.56	1.3	2.9	.12	1	.1	.22	3.1	.34	1	.33	.7	10.2	2.3	12.5
.13	1	.56	.7	1.4	.06	1	.1	.16	0	0	0	0	0	21.2	2.0	23.2
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.73	1	.56	1.3	2.9	.12	1	.1	.22	3.1	.34	1	.33	.7	10.3	3.6	13.9
0	0	0	0	1.1	.04	1	.1	.14	0	0	0	0	0	22.3	2.7	25.0
0	0	0	0	.85	.03	1	.1	.13	0	0	0	0	0	.73	1.4	2.1
.73	1	.56	1.3	2.9	.12	1	.1	.22	3.1	.34	1	.33	.7	10.3	3.6	13.9
0	0	0	0	1.1	.04	1	.1	.14	0	0	0	0	0	22.3	2.7	25.0
0	0	0	0	15.0	.6	2	.2	.8	7.7	.85	2	.66	1.5	27.2	7.5	34.7
.66	1	.56	1.2	3	.12	1	.1	.22	0	0	0	0	0	116	18	134
1.3	2	1.12	2.4	3	.12	1	.1	.22	0	0	0	0	0	208	52	260

APPENDIX II
PROBLEM IDENTIFICATION TEST COSTS

Problem identification test costs vs. required MTBR are shown in Figures 16 through 30 for 3-, 4-, and 6-year programs, for each case of each study variable.

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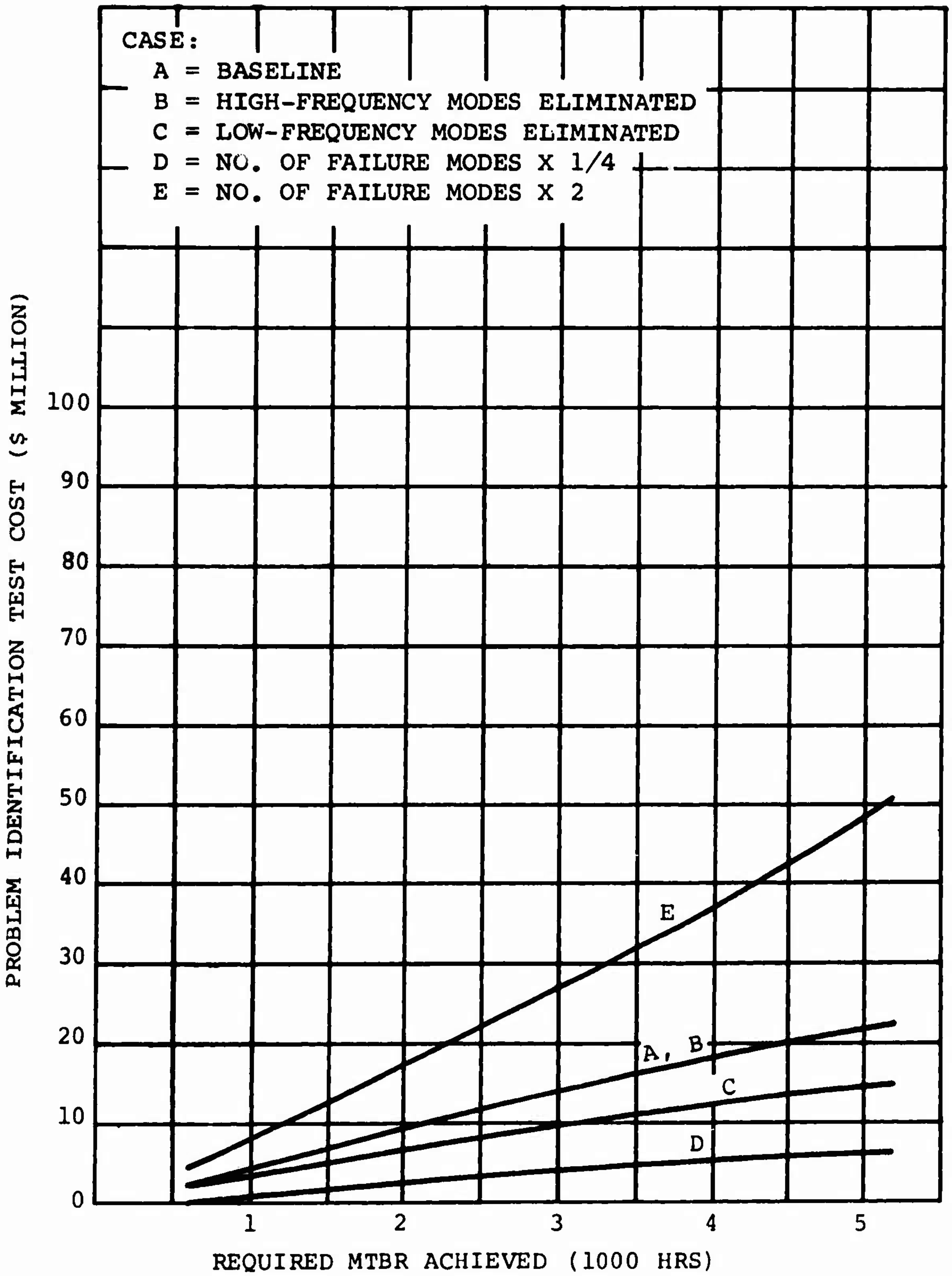

Figure 16. 3-Year Program MTBR Off-the-Board Sensitivity - Problem Identification Test Costs for Required MTBR's.

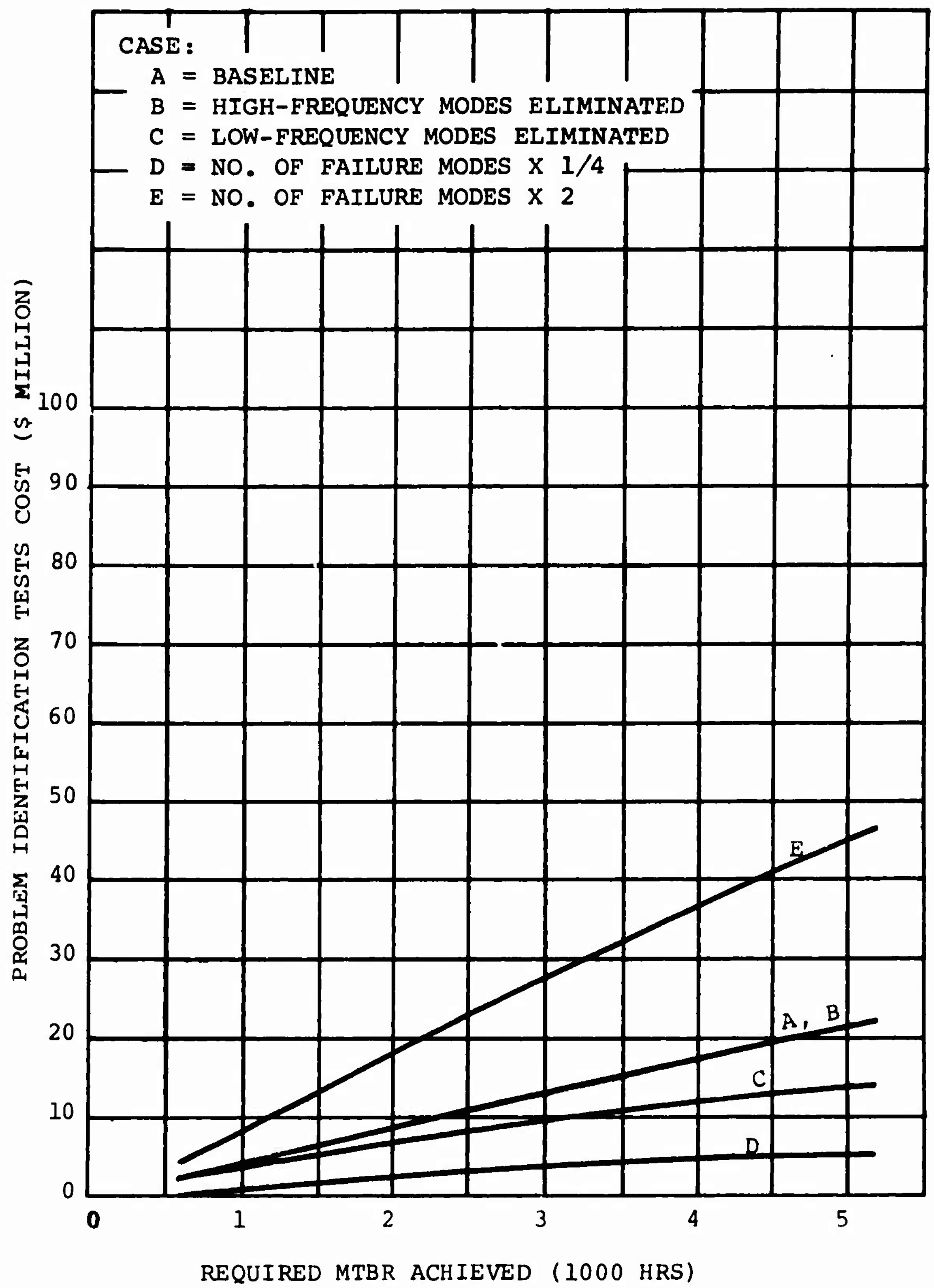

Figure 17. 4-Year Program MTBR Off-the-Board Sensitivity - Problem Identification Test Costs for Required MTBR's.

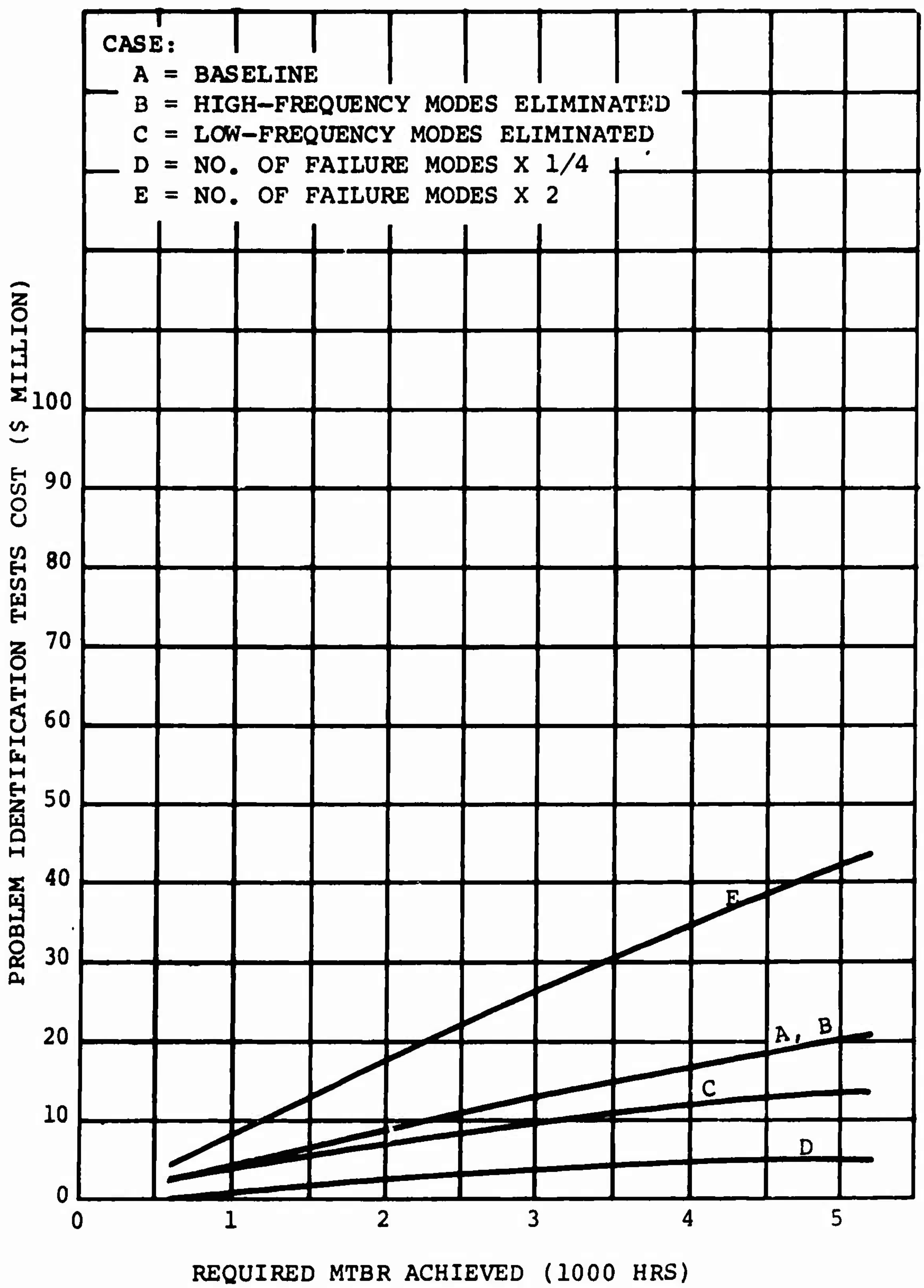

Figure 18. 6-Year Program MTBR Off-the-Board Sensitivity - Problem Identification Test Costs for Required MTBR's.

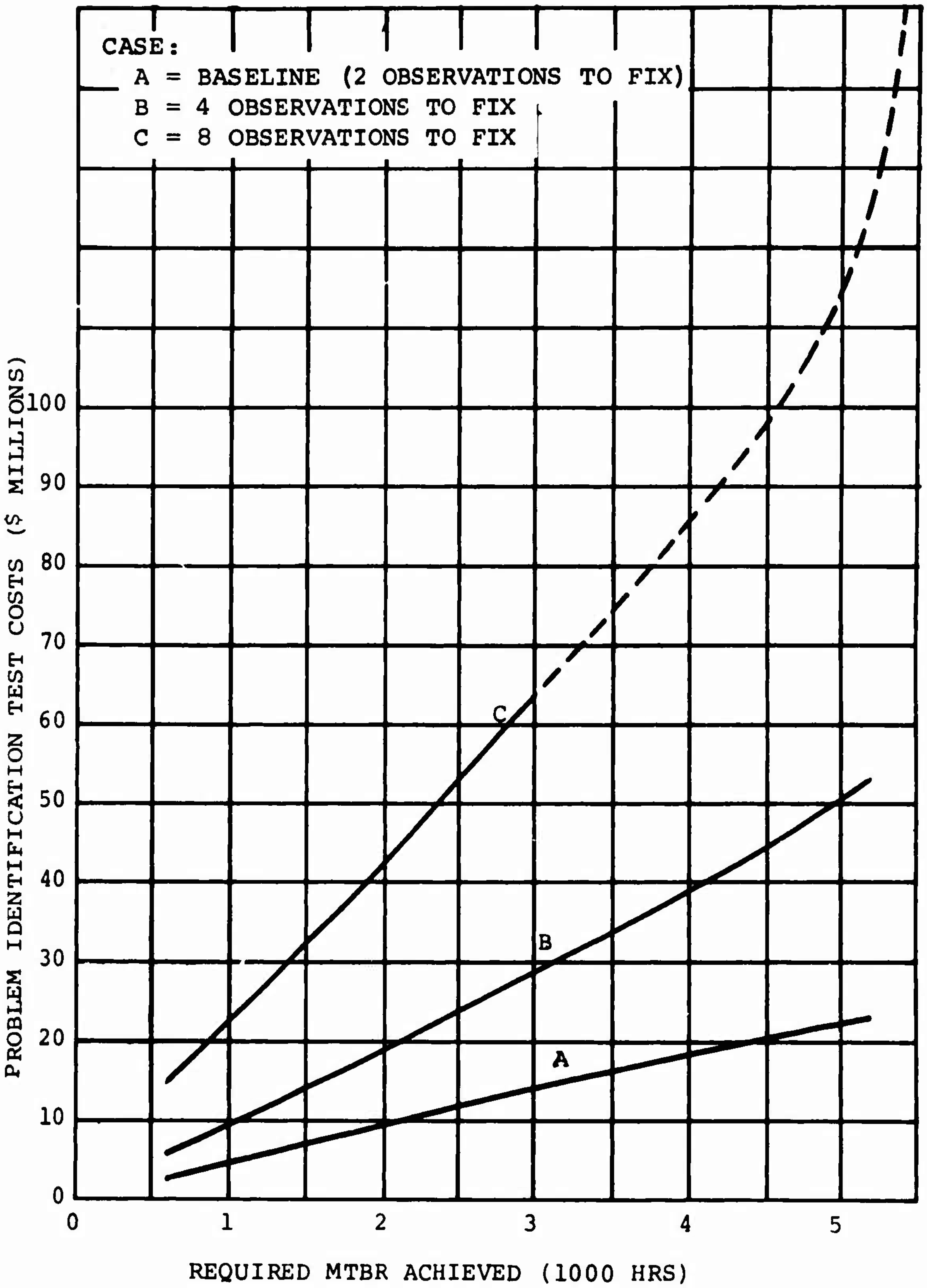

Figure 19. 3-Year Program Corrective Action Efficiency Sensitivity - Problem Identification Test Costs for Required MTBR's.

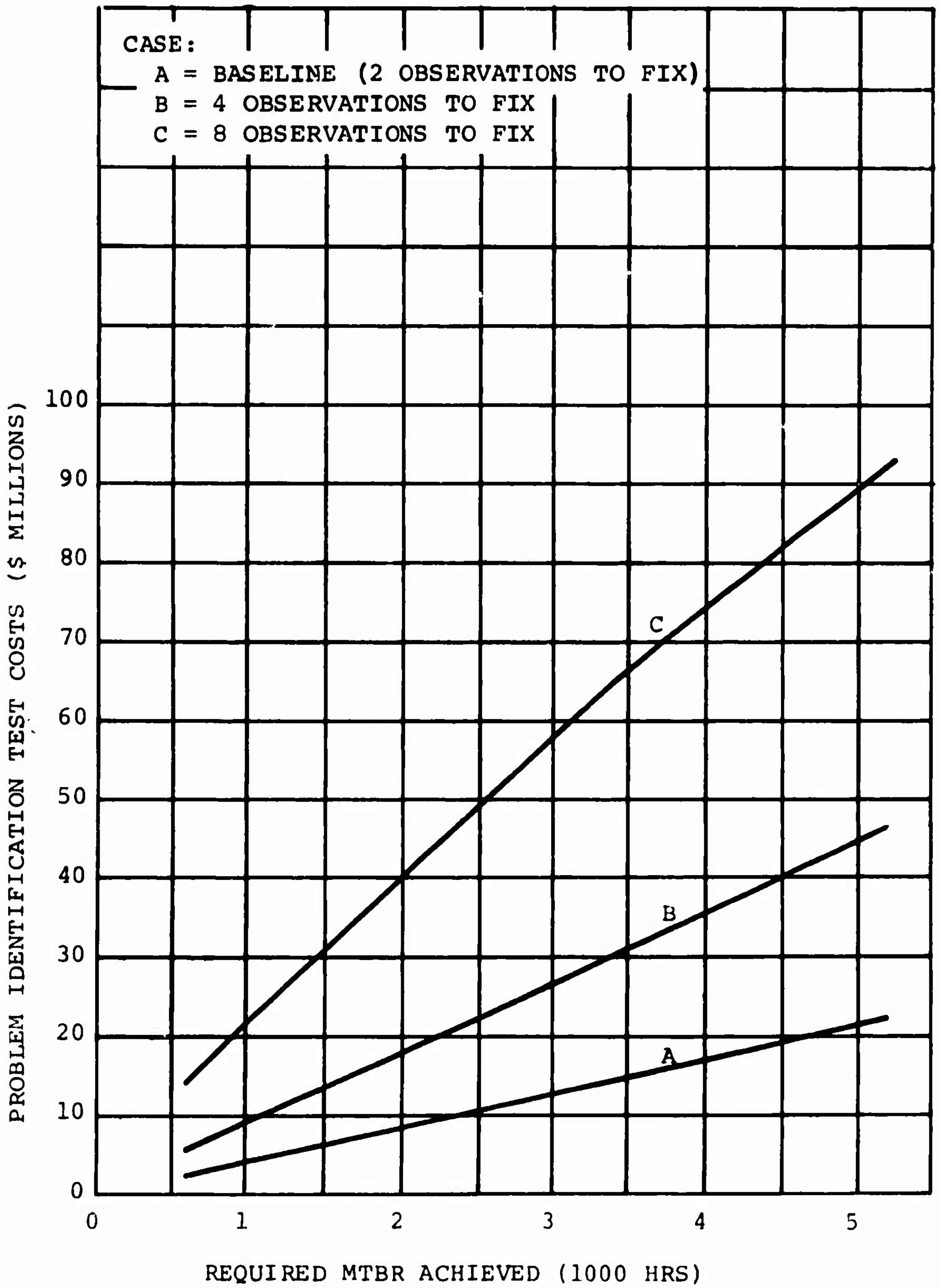

Figure 20. 4-Year Program Corrective Action Efficiency Sensitivity - Problem Identification Test Costs for Required MTBR's.

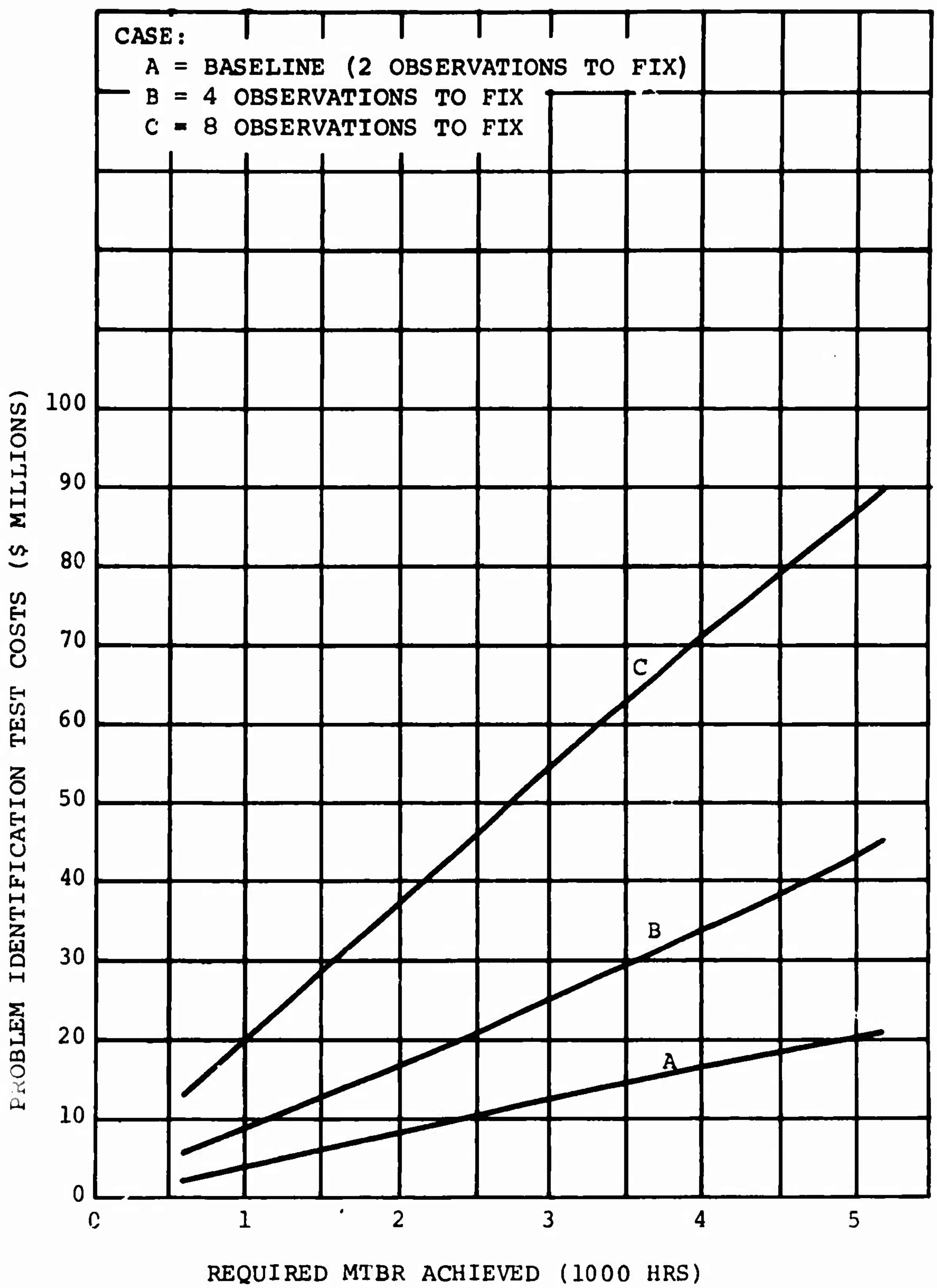

Figure 21. 6-Year Program Corrective Action Efficiency Sensitivity - Problem Identification Test Costs for Required MTBR's.

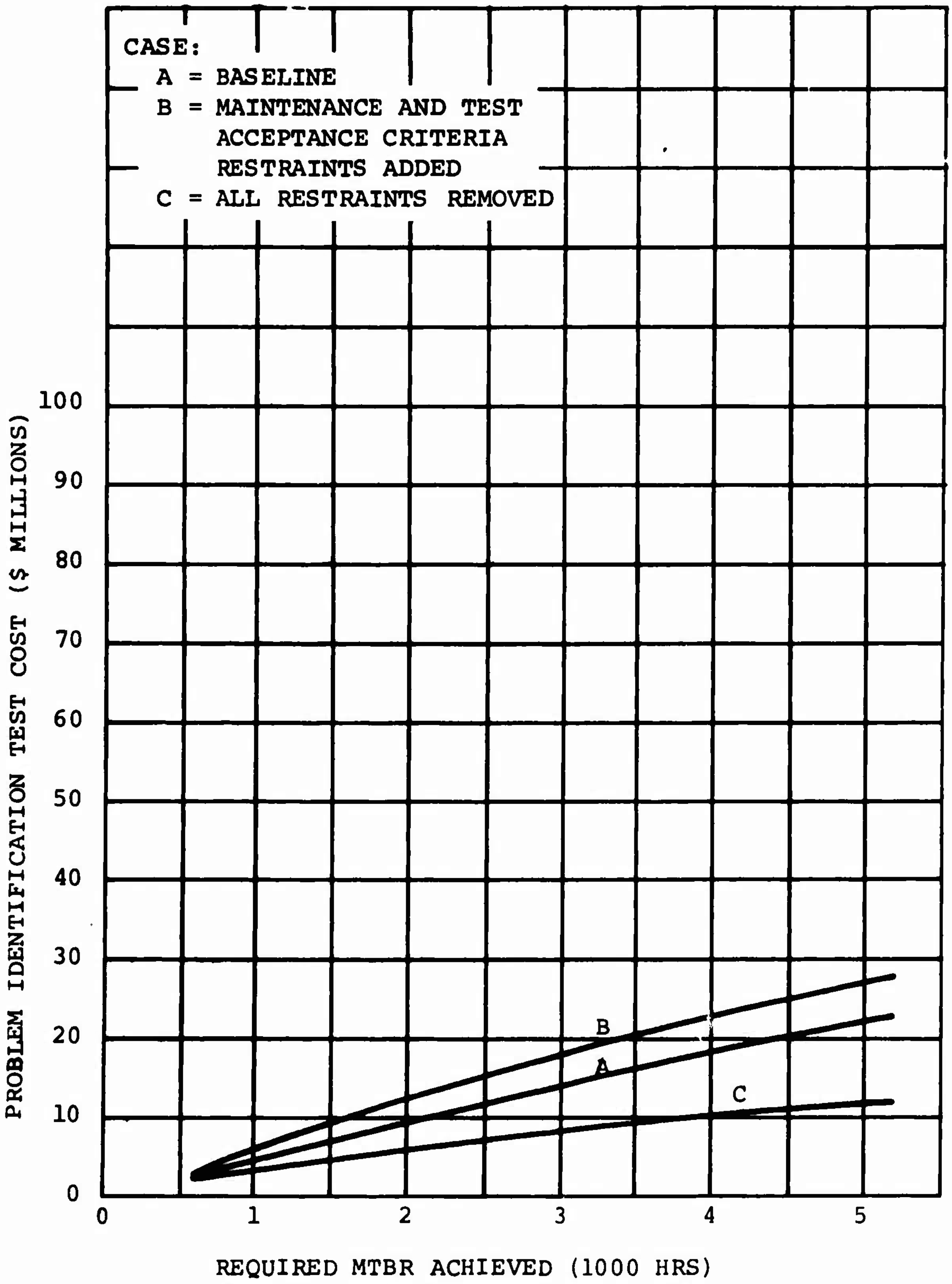

Figure 22. 3-Year Program Test Effectiveness Sensitivity - Problem Identification Test Costs for Required MTBR's.

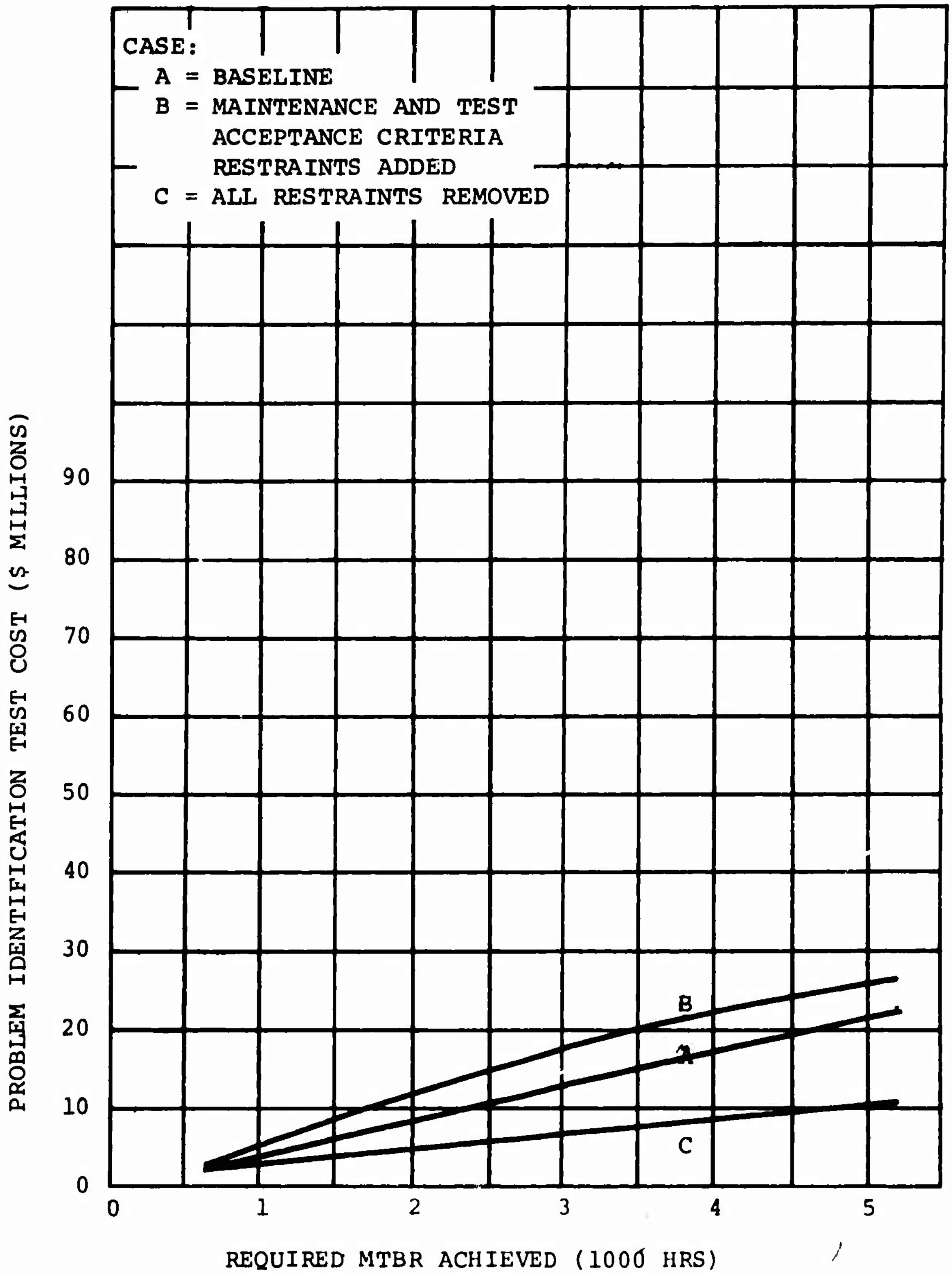

Figure 23. 4-Year Program Test Effectiveness Sensitivity - Problem Identification Test Costs for Required MTBR's.

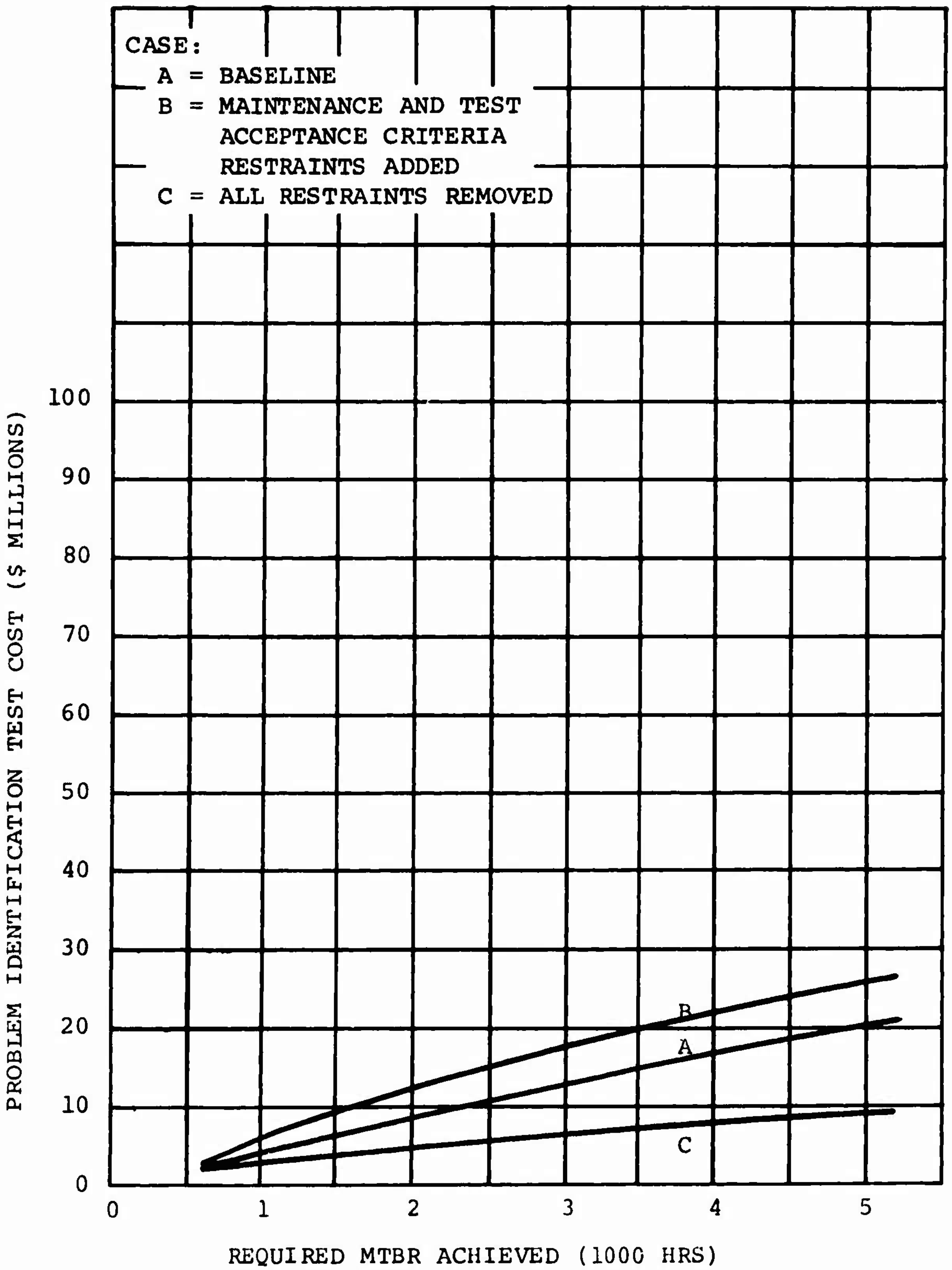

Figure 24. 6-Year Program Test Effectiveness Sensitivity - Problem Identification Test Costs for Required MTBR's.

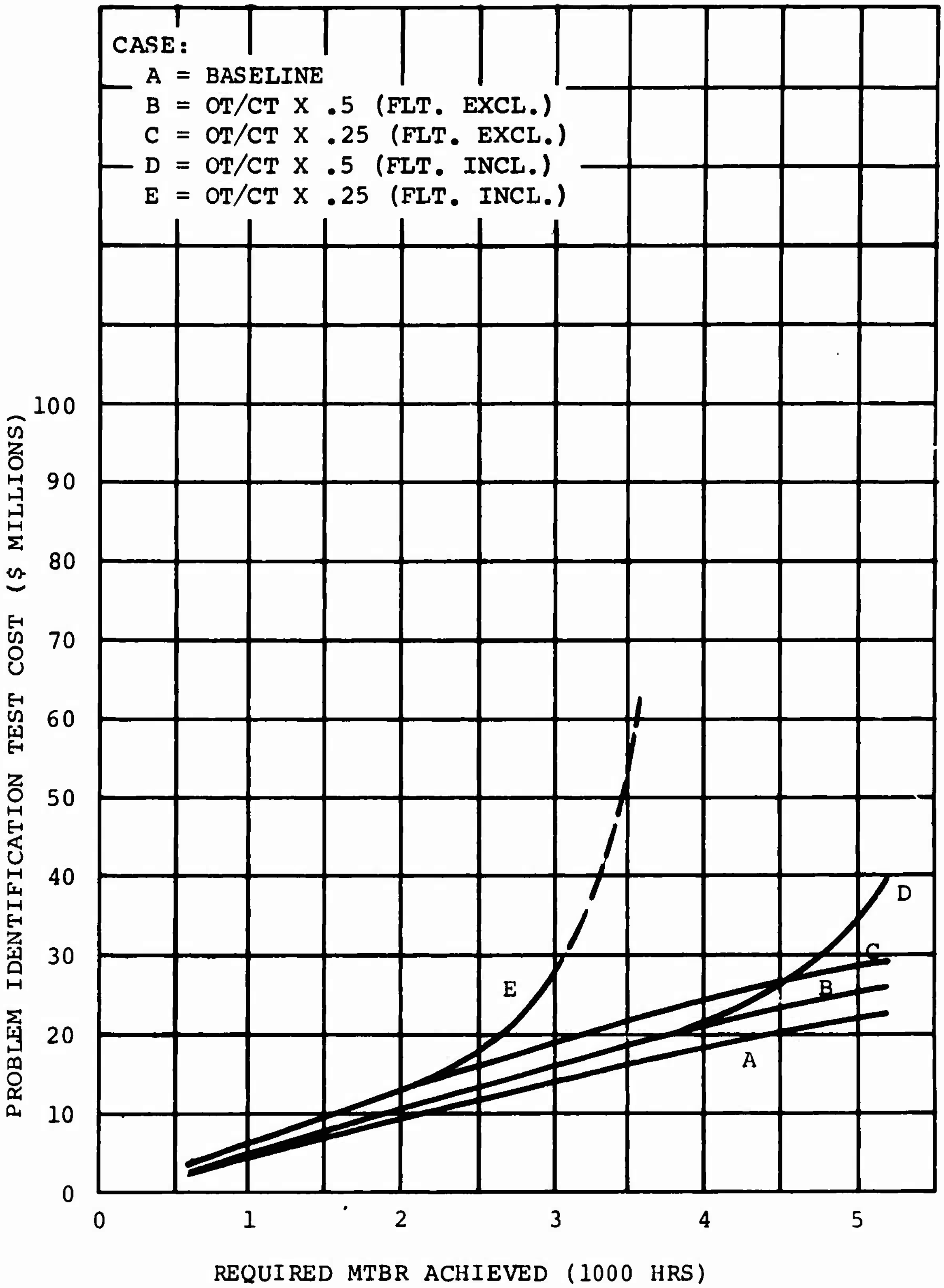

Figure 25. 3-Year Program Operating Time to Calendar Time Sensitivity - Problem Identification Test Costs for Required MTBR's.

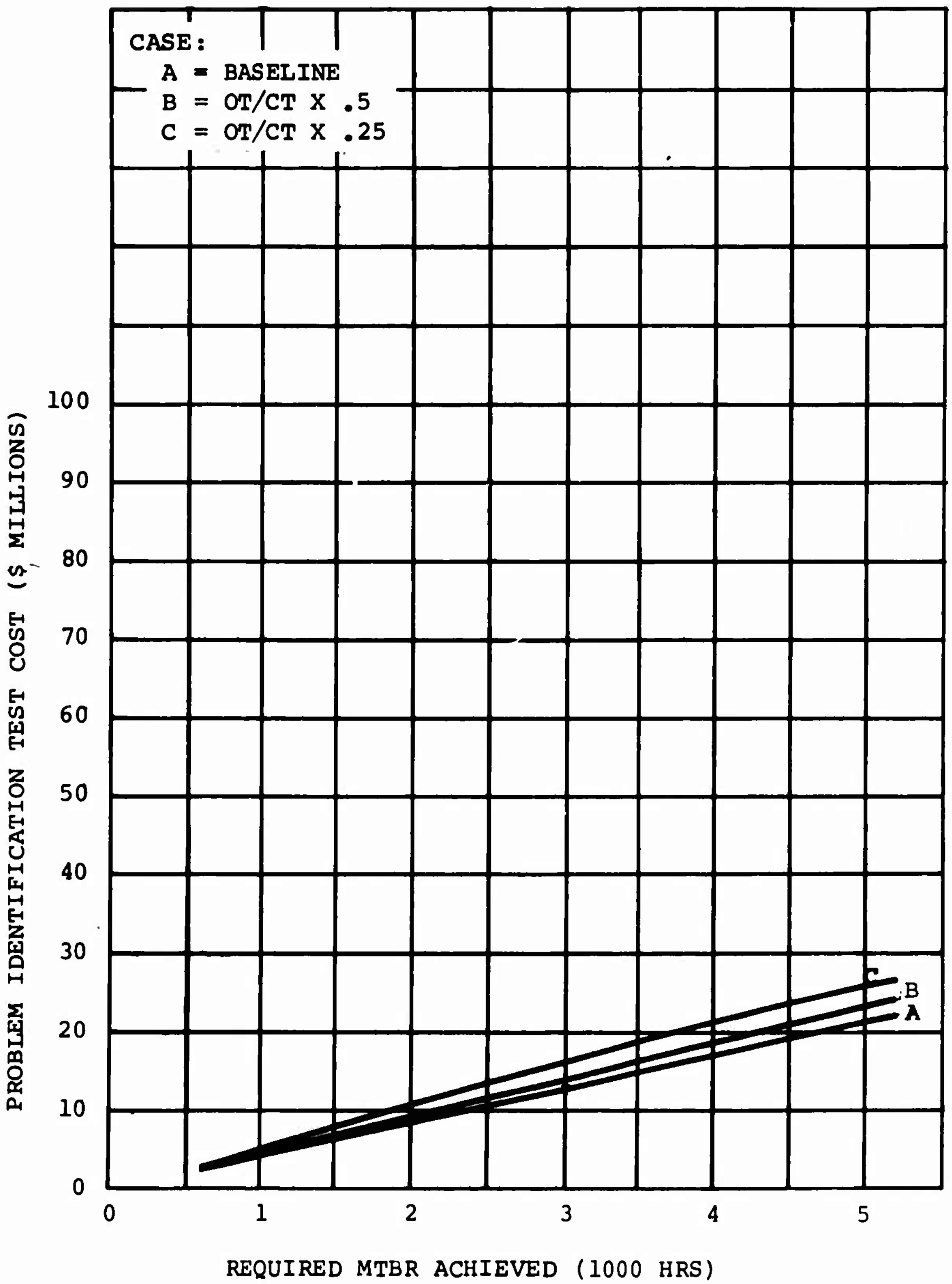

Figure 26. 4-Year Program Operating Time to Calendar Time Sensitivity - Problem Identification Test Costs for Required MTBR's.

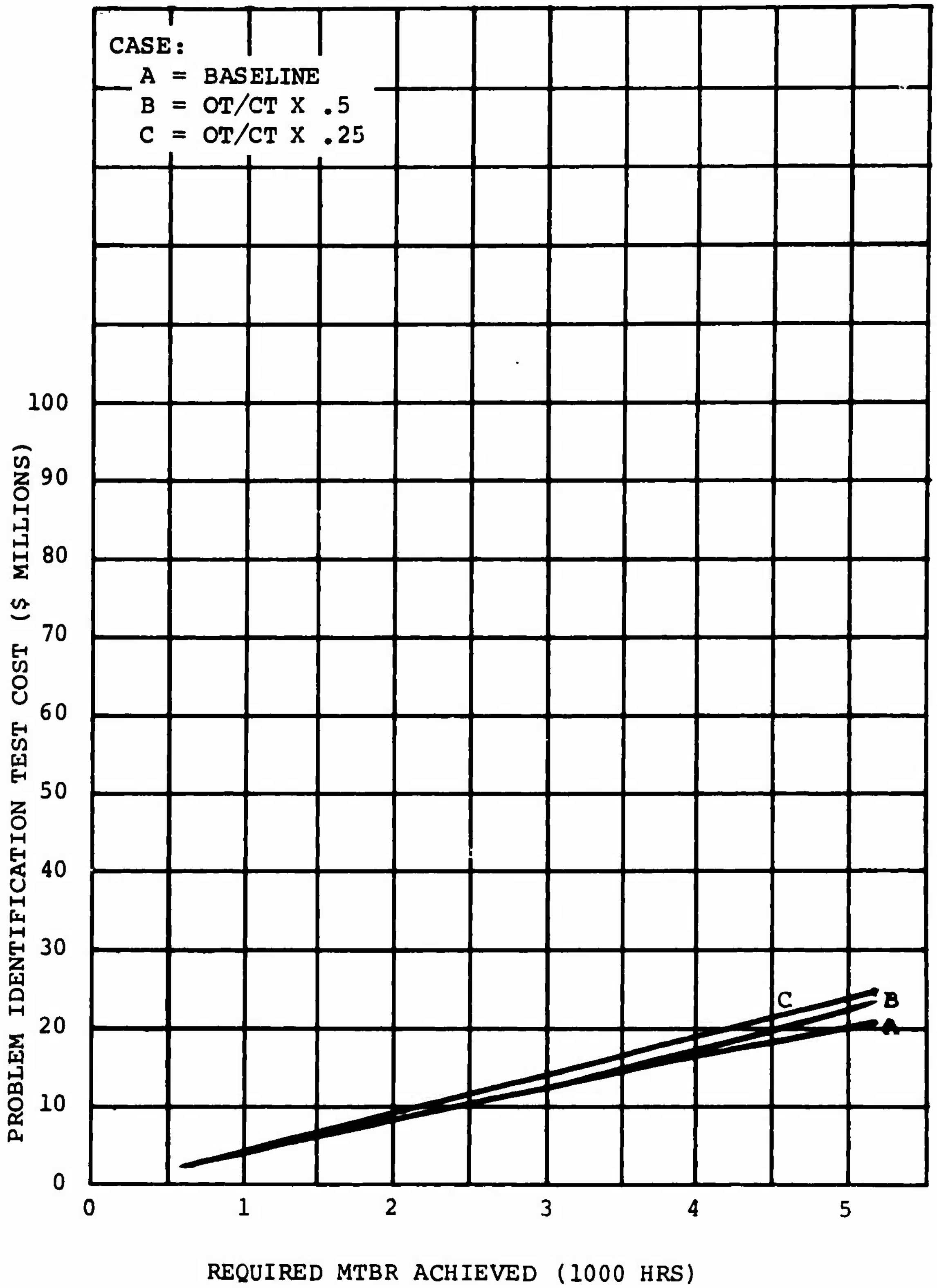

Figure 27. 6-Year Program Operating Time to Calendar Time Sensitivity - Problem Identification Test Costs for Required MTBR's.

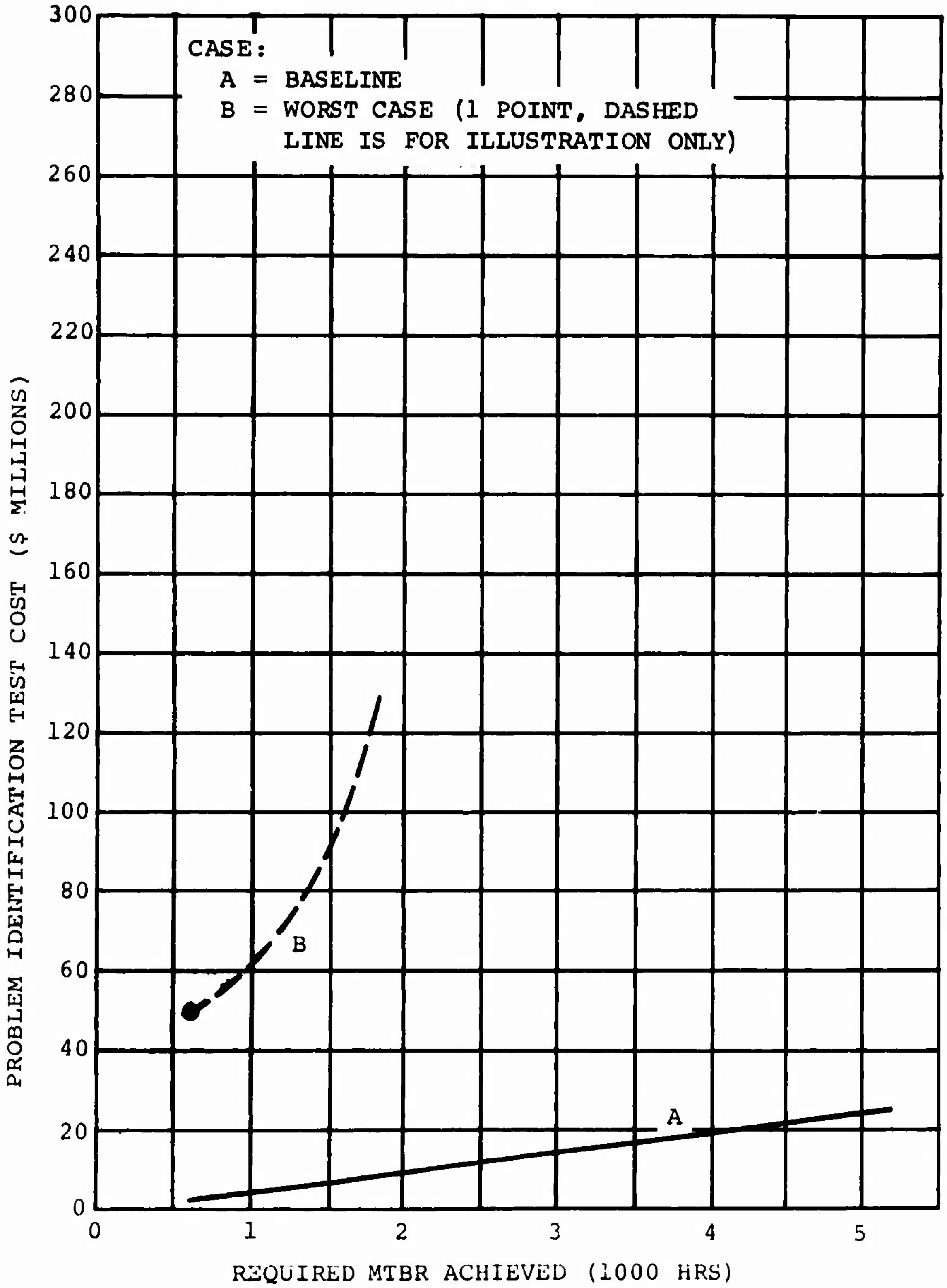

Figure 28. 3-Year Program Worst Case Analysis - Problem Identification Test Cost for Required MTBR's.

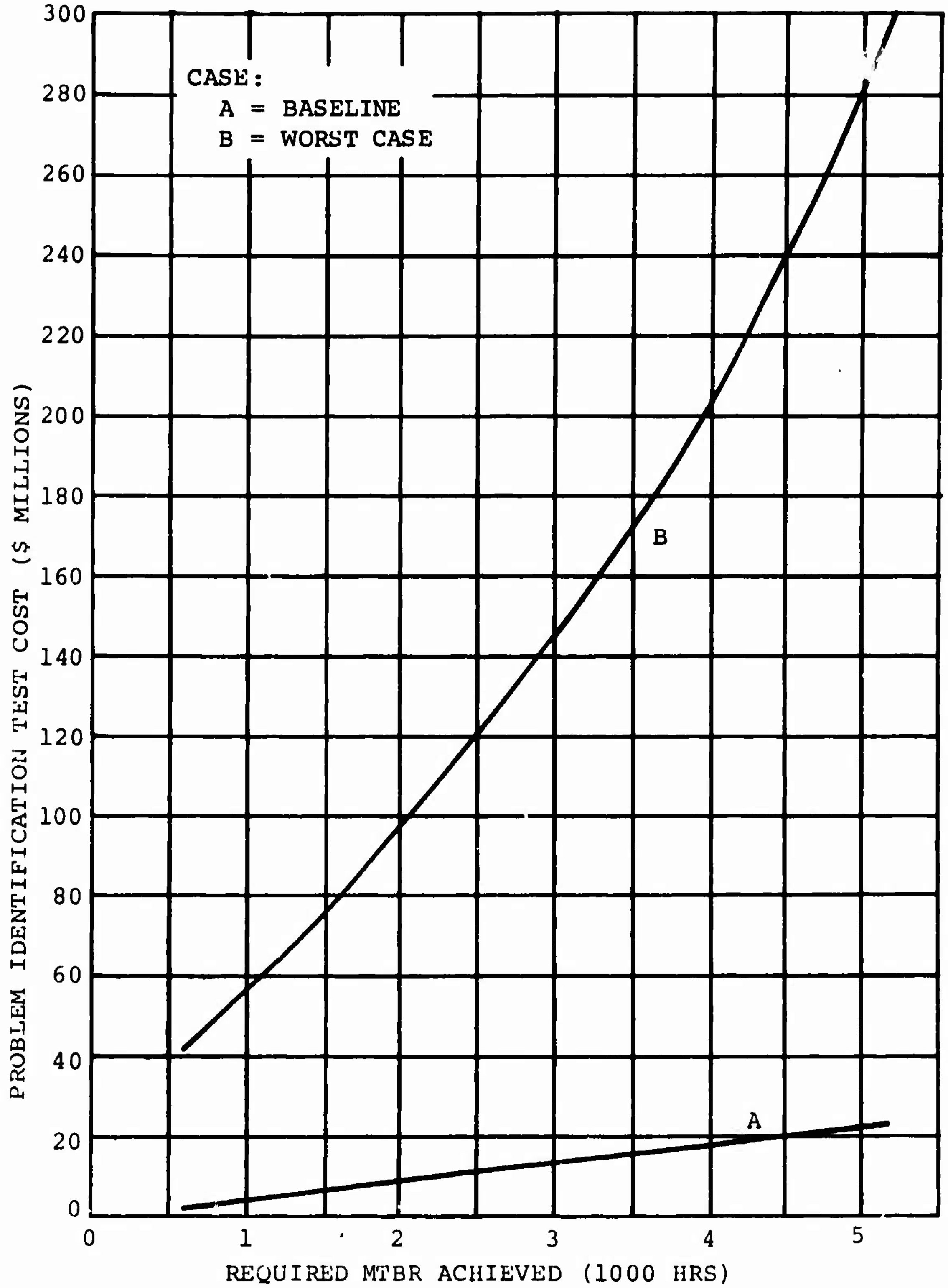

Figure 29. 4-Year Program Worst Case Analysis - Problem Identification Test Cost for Required MTBR's.

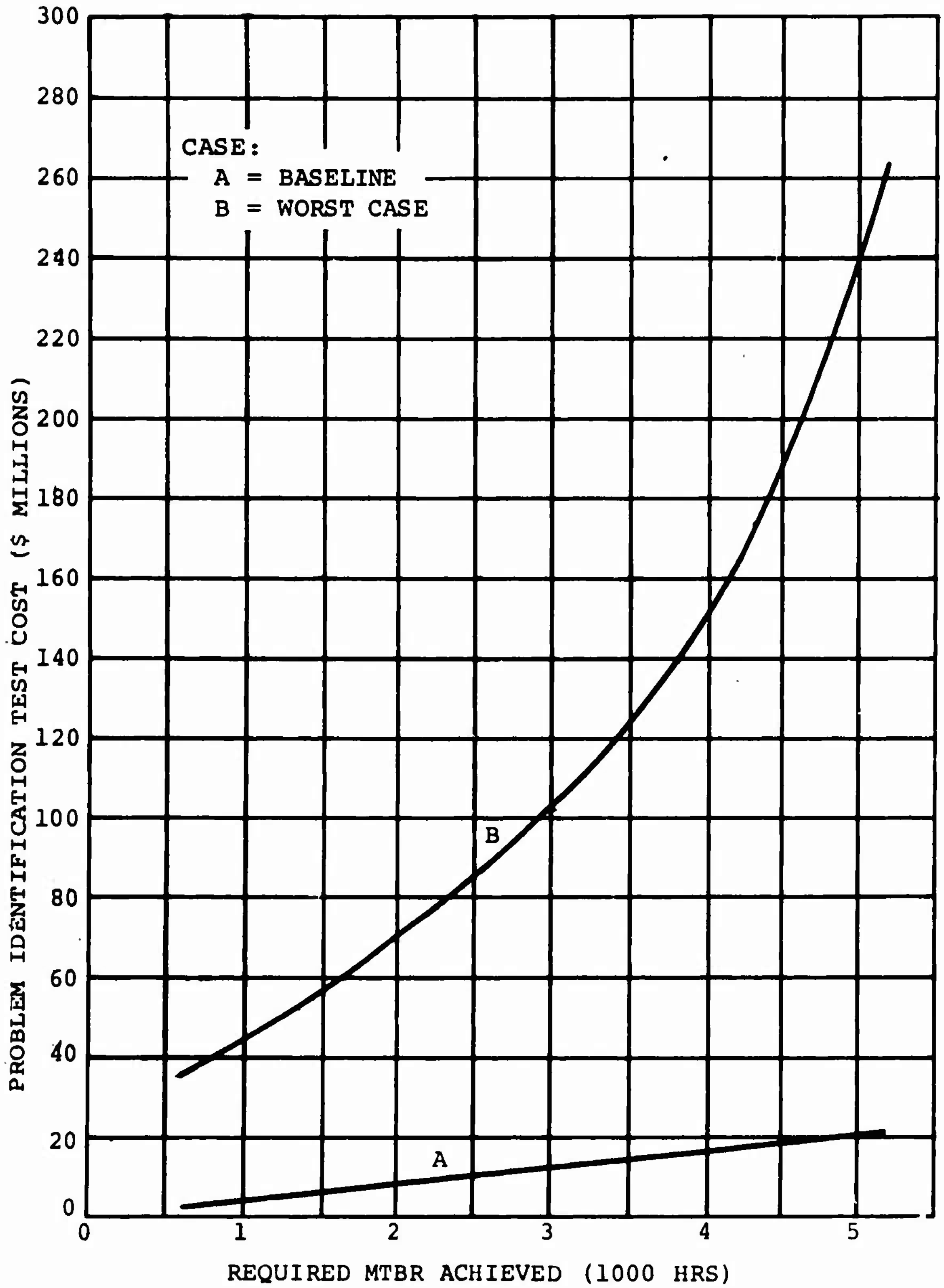

Figure 30. 6-Year Program Worst Case Analysis - Problem Identification Test Cost for Required MTBR's.